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WAR DEPARTMENT

TECHNICAL MANUAL

PHYSIOLOGICAL ASPECTS OF FLYING AND MAINTENANCE OF PHYSICAL FITNESS

July 25, 1941

TECHNICAL MANUAL No. 1–705

WAR DEPARTMENT,
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PHYSIOLOGICAL ASPECTS OF FLYING AND MAINTENANCE OF PHYSICAL FITNESS

Prepared under direction of the Chief of the Air Corps

SECTION I

GENERAL

1. Purpose.—*a.* The purpose of this manual is to instruct all flying personnel in the following:

(1) Those physiological aspects of flying which are detrimental to the normal functioning of the human body.

(2) The preventive or corrective measures to be taken to avoid or overcome these detrimental aspects.

(3) The necessity for maintenance of the required high standard of physical fitness for the proper performance of flying missions.

b. Incidental to its main purpose, the information compiled in this manual may serve to determine the causes of otherwise inexplainable accidents to aircraft and their crews. Likewise, through the intelligent application of the preventive and corrective measures outlined herein, recurrence of such accidents can be avoided.

2. Scope.—This manual begins with a description of the earth's atmosphere in order to impress the student with the characteristics of the medium in which he flies. It then discusses in sequence the effects upon the human body induced by altitude, by cold, by acceleration, and by centrifugal force induced by violent maneuver, explaining where possible the measures to be taken to offset these effects. The manual deals with the psychological aspects of flying, and discusses psychiatry insofar as it pertains to flying personnel. It then concludes with a discussion of the necessity for the highest standard of physical fitness in the selection of flying personnel and emphasizes the necessity for flying personnel to maintain themselves always in a state of physical fitness.

3. Method of presentation.—This manual is presented in textbook style. Technical medical terms have been omitted insofar as practicable, and an effort made to present the subject matter in a simple, easily readable, and interesting manner in order to promote self-instruction by all flying personnel through the use of this text.

4. Problems.—*a.* The human body is constructed by nature, through evolution, for the environment of normal living conditions on the earth's surface. The act of flying at varying altitudes above the earth's surface through the medium of the atmosphere induces upon the human body abnormal reactions and requires intricate bodily

adjustments in order to compensate for the sudden changes from normal environment. To offset these changes in environment produced by flying, three things are necessary:

(1) An understanding of the conditions to be encountered.

(2) A knowledge of the limitations of human endurance under such conditions.

(3) A knowledge of the measures to be taken to enable the human body to overcome these conditions.

b. The human element in flight is relatively the weakest factor and yet the most important; weak, because in modern flying the normal adaptive capabilities of the body are exceeded; most important, because it furnishes the brain and nervous system for the aircraft. The human element can be strengthened by proper dissemination of knowledge such as is compiled in this text, which should result in the adoption of proper precautionary and corrective measures by flying personnel, proper accommodation in aircraft design, provision of suitable flying equipment, and maintenance of a high standard of physical fitness by flying personnel.

c. Some of the many problems incident to flying and affecting flying personnel which are discussed in this manual are as follows:

(1) The selection of competent personnel.

(2) Accidents and failures caused by lack of experience or lack of information.

(3) Errors in judgment and causes.

(4) The many causes which produce fatigue or stress.

(5) Effects of oxygen deficiency at high altitude (anoxia).

(6) Effects of low atmospheric pressures at high altitudes (aeroembolism).

(7) Effects of centrifugal force, acceleration, and deceleration.

(8) Causes and effects of motion sickness.

(9) Spacial orientation; instrument flying, etc.

(10) Muscular coordination.

(11) Impairment of vision due to any one of several probable causes.

(12) Effects of cold (low temperatures).

(13) Effects of sun's rays at high altitudes.

(14) Parachute descent and delayed opening.

(15) Psychology as applied to aviation.

(16) Psychiatry in relation to flying personnel.

(17) The combined causes of staleness, fatigue, or stress.

(18) Physical fitness for flying.

Section II

CHARACTERISTICS OF EARTH'S ATMOSPHERE

5. Composition of earth's atmosphere and physical properties of gases.—*a.* It is highly desirable for all flying personnel to have some knowledge of the physics of the earth's atmosphere so that they may know what to expect from the various conditions they may encounter in flying. It is the purpose of this section to present a brief discussion of some of those important characteristics of the atmosphere the knowledge of which is of value from the physiological point of view.

b. This study of the atmosphere will be limited in scope only to that information which is essential as a basis for the understanding of subsequent sections of this manual. A more detailed study of the atmosphere near the earth's surface can be found in weather manuals and manuals on meteorology.

c. The earth is enveloped by a mixture of gases and water vapor which are held adjacent to it by the force of gravity. Observation and spectrum analysis of auroras indicate that the depth of this atmospheric and gaseous envelope is greater than 100 miles, and traces of some of the lighter gases are found at an altitude of 200 miles.

d. The vertical structure of the lower portion of the earth's atmosphere has been reliably determined by means of high altitude flights of airplanes, manned balloons, kites, and sounding balloons. Analysis of samples shows that the air is composed of a mixture of gases, and at mean sea level under average conditions, excluding water vapor, consists of approximately 78 percent nitrogen and 21 percent oxygen; the 1 percent remaining consists of traces of carbon dioxide, argon, hydrogen, helium, xenon, and crypton.

e. The water vapor content is important. It is variable but in the lower cloud areas will average about 1.2 percent. The percentage of moisture decreases at higher altitudes until the upper air is practically dry.

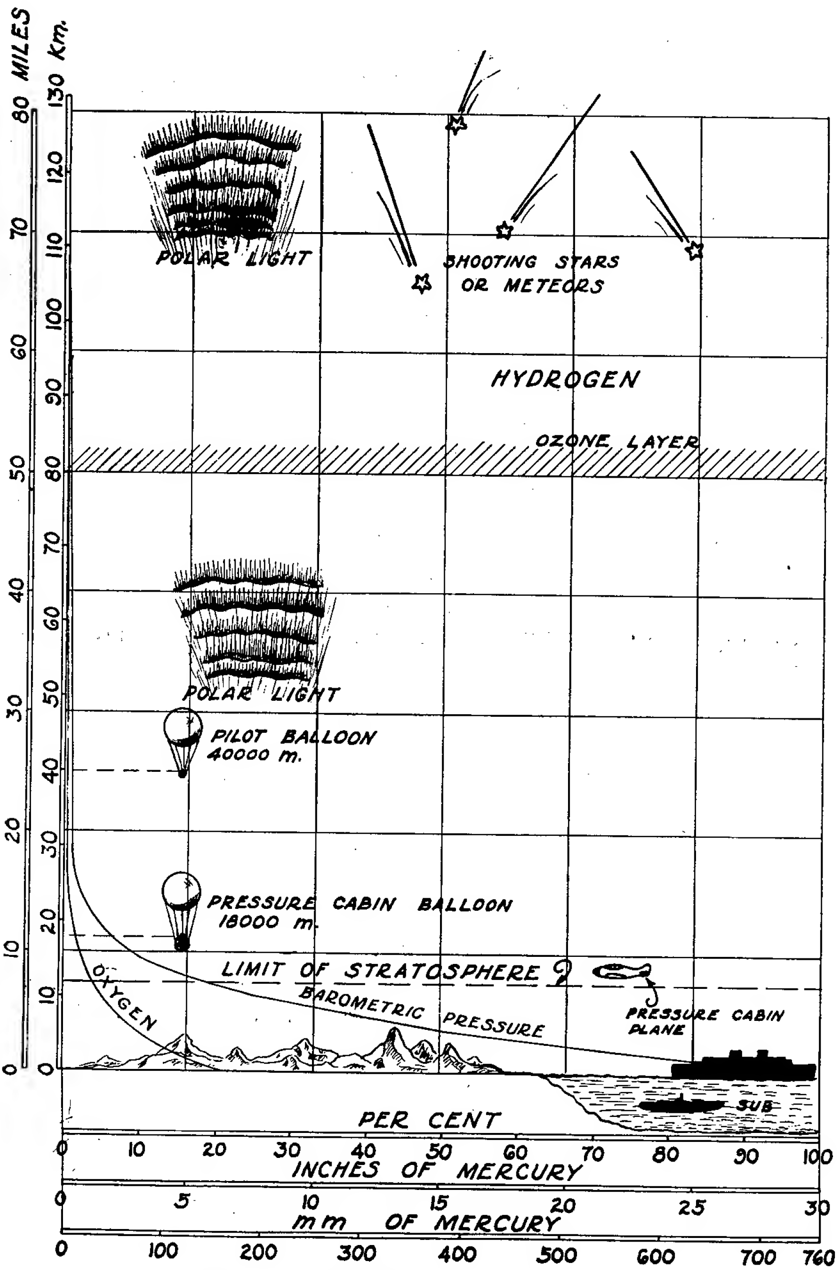

FIGURE 1.—Cross section of earth's atmosphere.

f. The relationship between atmospheric pressure, temperature, water vapor, and density of the mixture of gases conforms to certain known physical laws of gases. These laws are—

(1) *Boyle's law.*—At constant temperature, the volume of a gas varies inversely as the pressure.

(2) *Charles' law.*—At constant pressure, the volume of a gas varies directly as the absolute temperature.

(3) *Dalton's law.*—The pressure of a mixture of several gases in a given space is equal to the sum of the pressures which each gas would exert by itself if confined in that space.

g. Physical properties of gases.—To arrive at a proper understanding of the gaseous mixture called the atmosphere, the following physical properties of gases must be understood:

(1) Both liquids and gases are fluids.

(2) Fluids do not offer permanent resistance to forces tending to produce a change in shape.

(3) Gases are compressible.

h. Measure of density of gases.—The weight of the standard unit of volume of a gas is called the density of that gas. Expressed in another way, the density of a gas is the measure of the force of gravity acting upon the mass of a unit volume of that gas.

i. In the case of gases the conditions of pressure and of temperature are of such importance that it is impossible for them not to be taken into consideration. The gas used for purposes of comparison is air under established conditions of purity. The composition of the earth's atmosphere is remarkably constant, as previously stated, excepting for the proportion of water vapor it contains. This variability is eliminated by taking dry air as a standard of comparison. In determining the standard densities or specific gravities of air and other gases, the standard temperature is taken at 0° Centigrade (32° F.) and under a constant pressure of 760 millimeters of mercury (29.92 inches). Under these conditions of P and t, the standard density of dry air is 1.293 kilograms per cubic meter (0.08072 pound per cubic foot) and is the standard of comparison from which the specific gravities of all gases are determined.

6. Atmospheric pressure.—*a.* Atmospheric pressure is determined by the density of the air and is the weight of the column of air above the measuring instrument or above any particular point in space. Oxygen partial pressure is that part of the total atmospheric pressure which is exerted by the density of the oxygen content of the air. The variations of pressure with altitude are shown in figure 2 and table I.

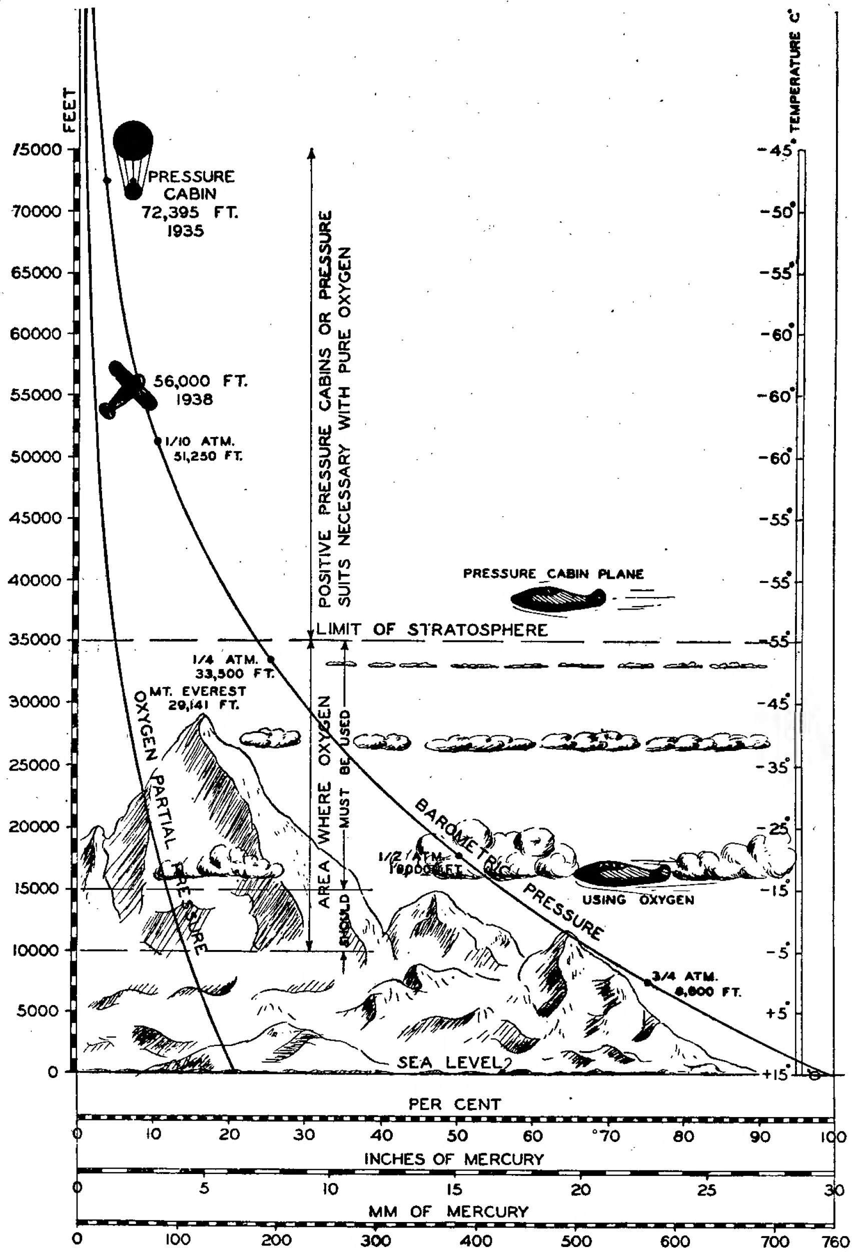

FIGURE 2.—Atmospheric layer of possible aerial operations.

b. The standard barometric pressure at sea level is 760 millimeters of mercury (29.92 inches of mercury), but as altitude increases the barometric pressure decreases. With the decrease in barometric pressure, there is a corresponding decrease in the partial pressure of oxygen, until an altitude is eventually reached where the oxygen pressure is insufficient to sustain life without the supply of oxygen by artificial means.

c. The partial pressure of each constituent of atmospheric air is the barometric pressure times the volume percent of the particular constituent. In the case of oxygen, with a volume percentage of 21 under an atmospheric pressure (weight) of 760 millimeters of mercury (29.92 inches), the partial pressure is 160 millimeters of mercury (6.3 inches) approximately.

d. The passage of the required amount of oxygen into the living tissues is determined by the oxygen partial pressure in the atmospheric air. In table I the temperatures, barometric pressures, and the oxygen percentage equivalents for these pressures, corresponding to various altitudes, are given:

TABLE I.—*Altitude pressure table to which is added the equivalent oxygen percent*

(Based on the United States Standard Atmosphere (1935))

Altitude (feet)	Pressure		Temperature		Equivalent oxygen percent
	Inches of mercury	Millimeters of mercury	° C.	Decrease ° C.	
0	29. 921	760. 0	15	0	20. 93
1,000	28. 86	732. 9	13	−2	20. 18
2,000	27. 82	706. 6	11	−4	19. 46
3,000	26. 81	681. 1	9	−6	18. 76
4,000	25. 84	656. 3	7	−8	18. 07
5,000	24. 89	632. 3	5	−10	17. 41
6,000	23. 98	609. 0	3	−12	16. 77
7,000	23. 09	586. 4	1	−14	16. 15
8,000	22. 22	564. 4	−1	−16	15. 54
9,000	21. 38	543. 2	−3	−18	14. 96
10,000	20. 58	522. 6	−5	−20	14. 39
11,000	19. 79	502. 6	−7	−22	13. 84
12,000	19. 03	483. 3	−9	−24	13. 31
13,000	18. 29	464. 5	−11	−26	12. 79
14,000	17. 57	446. 4	−13	−28	12. 29
15,000	16. 88	428. 8	−15	−30	11. 81
16,000	16. 21	411. 8	−17	−32	11. 34
17,000	15. 56	395. 3	−19	−34	10. 89
18,000	14. 94	379. 4	−21	−36	10. 45
19,000	14. 33	364. 0	−23	−38	10. 02
20,000	13. 75	349. 1	−25	−40	9. 61

TABLE I.—*Altitude pressure table to which is added the equivalent oxygen percent*—Continued

(Based on the United States Standard Atmosphere (1935))

Altitude (feet)	Pressure: Inches of mercury	Pressure: Millimeters of mercury	Temperature: ° C.	Temperature: Decrease ° C.	Equivalent oxygen percent
21,000	13. 18	334. 7	−27	−42	9. 22
22,000	12. 63	320. 8	−29	−44	8. 83
23,000	12. 10	307. 4	−31	−46	8. 47
24,000	11. 59	294. 4	−33	−48	8. 11
25,000	11. 10	281. 9	−35	−50	7. 76
26,000	10. 62	269. 8	−37	−52	7. 43
27,000	10. 16	258. 1	−39	−54	7. 11
28,000	9. 72	246. 9	−41	−56	6. 80
29,000	9. 29	236. 0	−43	−58	6. 50
30,000	8. 88	225. 6	−44	−59	6. 21
31,000	8. 48	215. 5	−46	−61	5. 93
32,000	8. 10	205. 8	−48	−63	5. 67
33,000	7. 73	196. 4	−50	−65	5. 41
34,000	7. 38	187. 4	−52	−67	5. 16
35,000	7. 04	178. 7	−54	−69	4. 92
36,000	6. 71	170. 4	−55	−70	4. 69
37,000	6. 39	162. 4	−55	−70	4. 47
38,000	6. 10	154. 9	−55	−70	4. 27
39,000	5. 81	147. 6	−55	−70	4. 06
40,000	5. 54	140. 7	−55	−70	3. 87
41,000	5. 28	134. 2	−55	−70	3. 70
42,000	5. 04	127. 9	−55	−70	3. 52
43,000	4. 80	122. 0	−55	−70	3. 36
44,000	4. 58	116. 3	−55	−70	3. 20
45,000	4. 36	110. 8	−55	−70	3. 05

e. The actual or relative percentage of oxygen in the air is the same at all altitudes but its density decreases with decreasing temperature and pressure and increasing altitude. Therefore, in order that oxygen may be available for the human consumption it must be available under a pressure great enough to maintain its density sufficiently to supply the lungs and the blood. If sufficient atmospheric pressure is not maintained, the percentage of oxygen in the air breathed must be increased until finally pure oxygen must be used at high altitudes. Low atmospheric density and pressures are hazardous to flying at high altitudes.

7. Atmospheric temperature.—*a.* In studying the vertical structure of the atmosphere, one is introduced to the terms "troposphere," "stratosphere," and "tropopause." They are used primarily to de-

scribe the main horizontal layers of the atmosphere as regards its vertical temperature distribution. The troposphere is that layer adjacent to the earth's surface wherein there is normally found a fall of temperature with increased altitude. The stratosphere is that portion of the atmosphere above the troposphere where there is no temperature fall with increased altitude, but in fact a slight rise. The tropopause is the layer or surface of demarcation between the troposphere and the stratosphere. The altitude of the tropopause is variable but generally closer to the earth's surface over polar regions than over equatorial regions. For the purpose of this manual it is sufficient to state that the stratosphere is the region in the atmosphere where temperature equilibrium exists. A section of the atmosphere showing the average temperatures, rates of changes in temperature, and vertical atmospheric pressure decrease at increasing altitude is illustrated in figure 2.

b. In the troposphere, the rate of temperature decrease with increase in altitude varies with the characteristics of the air, and it may happen at times that there is an increase in temperature with increased altitude within certain lower layers of the circulating air mass.

c. Low temperature (cold) has a detrimental effect upon the human being and therefore becomes a hazard to flying personnel. Exposure to cold will increase the demands upon the body (body metabolism). Metabolism is the chemical process in the body by which nutritive materials produce heat and energy and build up into living matter. An increase in metabolism calls for an increase in oxygen.

d. When engaged in cold weather flying, the pilot should always bear in mind the danger of ice forming on his airplane while at lower altitudes or during ascent to higher altitudes. Ice on the wings of an aircraft not only increases the load but also alters the aerodynamic characteristics of the airfoils in such a way that their lift is reduced. Once started, ice forms very rapidly, and the combined effect of increased load and reduced lift may be disastrous in flight. Then, too, the controls may become frozen due to a coating of ice. At higher altitudes where the atmosphere is dry this hazard is greatly reduced and finally eliminated.

8. Atmospheric moisture.—Attention has been invited to the fact that virtually all the moisture in the atmosphere is confined to the troposphere. This is evidenced by the lack of cloud forms in the stratosphere. Atmospheric moisture occurs in the form of water vapor, a liquid, or a solid (one of the several condensation forms). It is replenished by evaporation from the earth's surface and diminished by condensation and the subsequent precipitation. Moisture evaporated from the earth's surface is carried upward and diffused

by circulation and turbulence. Cooling by expansion, contact, or radiation may cause condensation, depending on the degree of saturation.

9. Atmospheric bumps.—The zone of the turbulent air, next to the surface of the earth, has been aptly termed the "surf-zone" of the atmosphere, and in it the aviator often experiences considerable bumpiness. All bumps may be said to be due to deflections in the horizontal wind, either upward or downward, and not to air pockets as was formerly believed. Bumpiness is one of the important factors of fatigue and motion sickness.

10. Influence of light and solar radiation.—*a.* The physiological and psychological influence of light is an important factor in military flying operations. The conditions of light determine the degree of vision during both day and night operations. The degree of visibility during the day and the condition of visibility will depend upon the conditions of the atmosphere, as well as upon the relative angle of the source of light—the sun. The visibility at night is likewise affected by atmospheric conditions, as well as by moonlight and starlight.

b. Light stimulates the chemical process in the body by which nutritive materials are built up into living matter. Light is considered healthful, although men and animals can live for a considerable period of time in darkness without harmful physical effects. Light, however, does have a physiologic influence. The effect of light is probably due to the photochemical reactions produced when light energy is absorbed, although the exact nature of this reaction has not been accurately determined.

c. In general, the shorter the wave length of light the greater the physiologic effect. The spectrum of sunlight reaches only 290 microns in ultraviolet light. Light waves less than 300 microns produce in all living cells a strong and often harmful reaction. Bacteria begin to die quickly at wave lengths of 296 microns or shorter.

11. Vertical structure of atmosphere.—*a.* There is very little change in the gaseous composition of the lower atmosphere within altitudes of practical flight. But the variables of the vertical structure are of vital importance to the airman, for upon the application of his knowledge of these his maximum flying efficiency and safety will depend.

b. The most important considerations of the vertical structure of the atmosphere and the effects upon the human body and senses as altitude is increased are as follows:

(1) Decrease in atmospheric pressure and density.

(2) Decreasing partial pressure and density of the vital oxygen.

(3) Decreasing temperature.
(4) Decreasing moisture content (humidity).
(5) Effects of light and solar radiation.

c. The aviator should keep in mind a graphical picture of the vertical cross section of the earth's atmosphere. Important variables of the atmosphere are shown graphically in figure 2. The curves are plotted against the vertical values of altitude given in feet. The altitudes shown are the maximum that have been reached by aircraft, the highest of which are at present considered the maximum altitudes of practical aerial operations of manned pressure-equipped aircraft. The approximate average values of important variable factors with changes of altitude are shown in figure 2 as follows:

(1) The barometric pressure change is given in three ways: inches of mercury, millimeters of mercury, and by a scale of percentage which may be applied to either system.

(2) The oxygen partial pressure is indicated in the same units as the barometric pressure. The average altitudes at which the use of oxygen should begin and at which oxygen must be used are indicated. The areas in which pressure cabin or pressure suits become necessary for the protection of personnel and preservation of normal functions are shown. However, the exact altitudes that can be reached without pressure compartments are slightly variable with different persons and conditions.

(3) The vertical temperature values are plotted against altitude in feet and are a mean value taken when the average surface temperature is +15° C.

(4) The extent of the moisture content in the atmosphere is in general indicated by the cloud level. Although the air tends to become dryer with altitude generally, and considerably dryer above the cloud level, there is little effect on human physiology as a result of the average changes of humidity encountered.

12. Effect of change in atmospheric factors with increasing altitude.—*a. General.*—As altitude is increased from sea level the variable factors influence the efficiency of flying personnel, and the several effects often combine to produce the hazardous conditions resulting during long combat missions at high or relatively high altitudes.

b. Change in altitude.—(1) Aside from the effects resulting from rapid changes in temperature, humidity, and possibly from variations in the intensity of ultraviolet radiation, changes in altitude pre-

sent two very difficult and different problems comprising the effects produced by—

(*a*) Changes in total pressure of the atmosphere (barometric pressure).

(*b*) Oxygen deficiency.

(2) In ascending from sea level atmospheric values to an altitude of approximately 8,500 feet, the atmospheric pressure and oxygen partial pressure are reduced approximately 25 percent and the body efficiency is also reduced. Upon reaching an altitude of 15,000 feet, it is only possible to maintain human operating efficiency by the use of oxygen by artificial means. When an altitude of 18,000 feet is reached, the atmospheric and oxygen pressures are reduced to 50 percent of sea-level values. The human body will not properly compensate for such large increases in altitude and permit efficient operation and activity under these conditions. Therefore, acute oxygen starvation will begin in a very short time.

(3) Additional factors which affect the functioning of the human body and may cause suffering above altitudes of 18,000 feet where the atmospheric pressure value of 50 percent or less is reached are as follows:

(*a*) The lag or difficulty in maintaining normal differential pressures between the exterior and interior body cavities, such as the sinuses and middle ear.

(*b*) The expansion of gases in the intestines and other parts of the body.

(*c*) Symptoms which result first of all from the lowered oxygen pressure, provided additional oxygen is not taken, and other symptoms believed to be a result of liberated nitrogen from the body tissues, commonly referred to as "aeroembolism" or "bends."

(*d*) It is of interest to note that at body temperature the blood will actually boil under conditions of low atmospheric pressure equivalent to 63,000 feet. Death would occur, however, long before reaching such an altitude.

(*e*) The boiling of the blood at extremely high altitudes which will cause death.

(4) The foregoing discussions in this section show that the four considerations of greatest importance in ascending to high altitudes in the earth's atmosphere are—

(*a*) Oxygen-want or starvation, known in aviation medicine as "anoxia."

(*b*) The expansion of gases within the body cavities and hollow organs.

(*c*) The effects of reduced external pressure which will cause bubbling of the blood and other body liquids, known in aviation medicine as aeroembolism or bends.

(*d*) Low atmospheric temperatures.

(5) During operations at low altitudes the body will partly compensate for the atmospheric changes, but as altitude is increased oxygen-want and its symptoms become apparent.

(6) At higher altitudes the consideration of sufficient external pressure to maintain the internal body pressures becomes imperative.

(7) Different physiological effects are produced by the rate of change and by the degree of change in barometric pressure.

(8) These considerations will be discussed in greater detail, under the proper headings, in the sections that follow.

Section III

EFFECTS UPON HUMAN BODY OF INCREASED ALTITUDE AND DECREASED OXYGEN PRESSURE IN ATMOSPHERE

13. Anoxia (effects of oxygen-want).—*a.* Anoxia is defined as oxygen deficiency—insufficient oxygen to maintain proper tissue oxidation. The symptoms which result from a rapid aircraft ascent should not be confused with—

(1) The airsickness which results from rolling and pitching motions.

(2) The symptoms which are common to mountain climbers.

(3) The condition referred to as aeroembolism or bends.

b. All vital processes in the body are dependent upon oxygen which is brought from the lungs to the body cells by the blood. If the oxygen pressure in the air breathed falls below the required limit, then the blood and the tissue cells are not sufficiently supplied with oxygen and the person suffers from altitude sickness, anoxia. Anoxia may be either acute (of short duration) or chronic (of long duration). The level at which the average healthy young individual begins to be affected from anoxia is between 8,000 and 12,000 feet.

14. Respiration (act of breathing).—*a.* To understand the cause of oxygen-want with increasing altitude it is necessary to understand the fundamentals of respiration. The atmosphere contains at

all altitudes approximately 21 percent oxygen, but with increase of altitude the pressure and density of air and of oxygen decrease according to the rate shown in table I.

b. It is the partial pressure or density of oxygen in the lungs that permits its diffusion through the alveolar walls of the lungs into the blood. As the barometric pressure and density of the atmosphere are decreased with altitude, likewise the oxygen partial pressure and density are decreased and therefore the blood absorbs less and less oxygen. Finally a point is reached at which the cells of the body do not get enough oxygen and they begin to lose their ability to perform their normal functions. As the altitude increase continues, the body cells finally become damaged and unable to function at all. Unless this condition is corrected, the cells and consequently the organisms die. It is well to remember that anoxia will not only stop the machine but will wreck the machinery.

c. Respiration is the function by which air is drawn into and expired from the lungs. In a physiological sense, respiration refers to the gaseous exchange between the organism and its environment. Air has a composition of gaseous elements which are suitable and essential to the existence of the body in its normal environment. There are two processes by which respiration is accomplished:

(1) The gaseous exchange between the lungs and the outside atmosphere (external respiration).

(2) The interchange between the blood and the tissue elements (internal respiration).

d. The necessary and constant renewal of air in the lungs is made possible primarily by movements which constitute normal breathing. These breathing movements are effected by means of distinct mechanisms in the body.

e. In addition to the reflex control of respiration, there are equally important chemical factors which control the normal rate and depth of breathing. Each function so influences the other that they cannot be considered as separate entities.

f. Figure 3 illustrates some of the important considerations of respiration which are self-explanatory.

g. There is an average critical altitude for flying personnel, which varies with different persons, above which the oxygen pressure is too low to sustain human efficiency and even life itself.

15. Harmful effects of oxygen-want.—*a*. It has been found that in a person acclimatized to sea-level conditions an ascent to only 6,000 feet or less is necessary before oxygen-want begins to develop. Unforunately, the first and principal effect is an anesthesia-like

RESPIRATORY SYSTEM	BODY SIZE		
FUNCTIONAL DIVISIONS	SMALL	AVERAGE	LARGE
TIDAL AIR	350 CC	500 CC	650 CC
SUPPLEMENTAL AIR	1500 CC	1700 CC	1900 CC
COMPLEMENTARY AIR	1500 CC	1700 CC	2000 CC
VITAL CAPACITY	3350 CC	3900 CC	4550 CC
DEAD SPACE	100 CC	140 CC	200 CC

DEFINITIONS:-

TIDAL AIR - AIR WHICH ENTERS AND LEAVES BODY WITH EACH NORMAL (RESPIRATION) BREATH.

SUPPLEMENTAL AIR - AIR WHICH CAN BE FORCIBLY EXPIRED AFTER A NORMAL TIDAL EXPIRATION.

COMPLEMENTAL AIR - AIR WHICH CAN BE FORCIBLY INSPIRED AFTER A NORMAL TIDAL INSPIRATION.

RESIDUAL AIR - AIR WHICH CANNOT BE VOLUNTARILY EXPELLED FROM LUNGS.

CC - CUBIC CENTIMETERS.

CO_2 - CARBON DIOXIDE

O_2 - OXYGEN

N_2 - NITROGEN

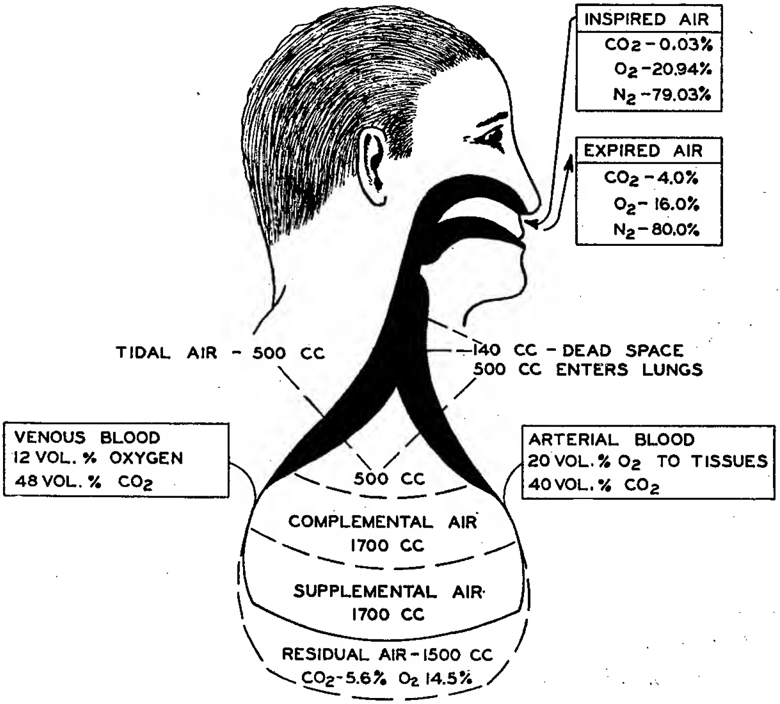

FIGURE 3.—Functional division of respiratory system.

reaction in which the senses are dulled, and consequently the actual effects upon the body are masked so that the flyer is wholly unaware of them. However, that the body is being damaged is well demonstrated by a stay at an altitude of from 8,500 to 12,000 feet for from 12 to 24 hours, following which an attack of mountain sickness may develop. The symptoms of mountain sickness consist principally of nausea, vomiting, headache, diarrhea, muscular weakness, and great general depression and prostration. This may last for only 1 or 2 days after return to lower altitudes but has been known to exist for as long as 4 weeks.

b. As altitudes above 12,000 feet are reached, the symptoms of oxygen-want appear more quickly and are due principally to the effects on the nervous system, as at lower altitudes the anesthesia-like effect dominates the body and the individual is in most instances unaware and ignorant of his precarious condition, although it is easily demonstrated that he is becoming more and more incapacitated as the ascent and time continue.

c. The cells of the brain are most sensitive to lack of oxygen, which affects the judgment and likewise the ability to judge correctly the degree to which one is being affected. A person seated at rest in an airplane does not always realize the effects of lack of oxygen, except physical and mental weariness, and may not realize a lessening of mental activity, particularly of attention, observation, and judgment. Digestion is often impaired and the heat mechanism of the body may be lowered in efficiency.

d. The extraordinary demands on the muscles and nervous system imposed by air combat will accentuate these conditions, and unless the proper amount of oxygen is supplied, a loss of muscular control, visual defects, and general impairment of mental functions result.

16. Symptoms of anoxia.—Individuals react differently without an artificial oxygen supply as altitudes and time are increased. But as ascents continue above 12,000 and 15,000 feet the average symptoms and effects can be summarized as follows:

a. At first there is a loss of the sense of feeling and pain which, to a great extent, probably explains the absence of physical distress, and at about the same time a temporary deterioration or lessening of the brain functions occurs.

b. At altitudes around 18,000 feet the first effects on the higher mental centers become definitely established and are characterized by loss of judgment, dulling of the intellect, loss of emotional stability, development of fixed irrational ideas, loss of muscular control, and a temporary loss of memory. This becomes progressively worse with

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the increase of time spent at that altitude and also as the altitude is increased.

c. By the time 20,000 to 25,000 feet is reached there may be fits of laughing or crying, impatience, rage, or other emotional disturbances, and great muscular weakness or paralysis. Vision at this altitude is usually affected. The muscular incoordination, or paralysis, affects the muscles of the eyes so that depth perception may become faulty and double vision may occur. In some cases there is a state of exhilaration resembling mild alcoholic intoxication during which a feeling of unusual well being and high efficiency is felt although the victim is very low in efficiency and may be approaching unconsciousness. Certain other individuals only get sleepy and pass into stupor.

d. At altitudes above 25,000 feet the system is usually overcome and unconsciousness intervenes, and if not soon relieved may cause mania, paralysis, blindness, permanent loss of memory, and nerve tissue destruction.

e. In personnel who are physically unfit, failure of respiration, heart failure, and unconsciousness may occur abruptly at high altitudes. Normal persons in good physical condition will lapse into rigid glassy-eyed coma, their respiration gradually ceases and finally their hearts stop if an artificial oxygen supply is not provided. Table II illustrates different symptons of oxygen-want at various altitudes of nine different persons.

f. The sudden removal of the oxygen supply at 30,000 feet produces gross mental and physical inefficiency in from 30 to 60 seconds and induces complete unconsciousness in from 60 to 90 seconds. Even during a fast descent from these high altitudes without oxygen, dangerous unconsciousness results after 90 seconds during the dive, lasting until about 20,000 or 17,000 feet is reached and consciousness begins to return.

g. Severe or prolonged oxygen-want may cause mental retardation and confusion for considerable time after the oxygen supply has been replenished, and permanent injury may result.

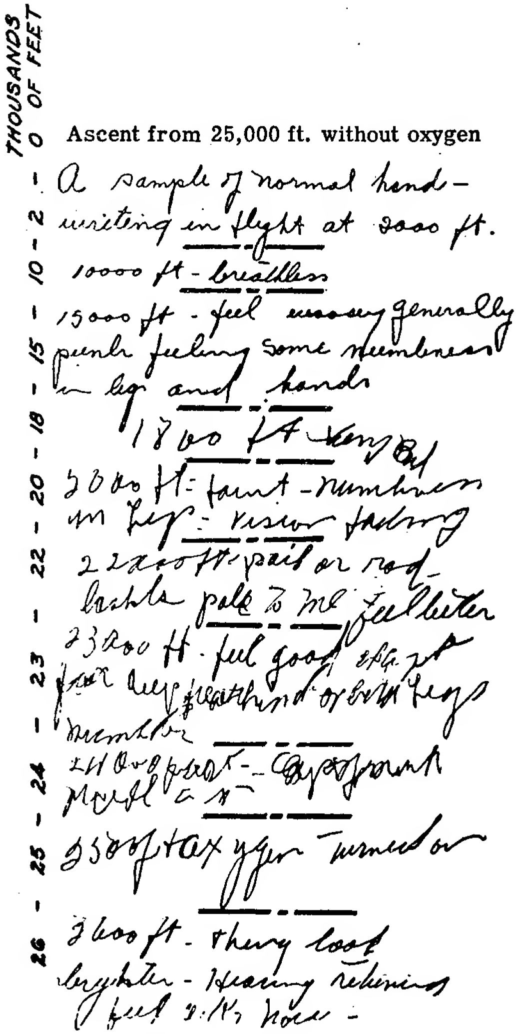
17. Illustrated examples of effects in flight of oxygen-want.—*a.* Among many experiments conducted to determine the effects of altitude and oxygen deficiency, a very interesting one consisted of taking notes during ascent to the highest altitude to which the subject could go without oxygen and retain consciousness. Another test was made during the discontinuance of oxygen use from 30,000 feet while descending at a rate of 2,000 feet per minute. Since irregularities in handwriting have been accepted as a good index of the effect of oxygen-want, requiring attention, judgment, concentration, ideation, and coordination, the two specimens obtained are

TABLE II.—*Symptoms of oxygen-want at various altitudes*

(Showing the symptoms and alterations in behavior produced by oxygen-want upon the subjects used in altitude experiments based upon the objective and introspective reports at approximately the altitudes and the oxygen percentages indicated.)

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
11.43% O_2 (17,000 ft.) 10.25% O_2 (20,000 ft.) 9.25% O_2 (23,500 ft.)	Cheerful. Jovial mood accentuated. Improvement on simple reactions. Dizziness. Fatigue and sleepiness. Worried and depressed expression. "Feel very tired and sleepy." Irritated.	Nervous. Slight tremor in hands. "Feel very cheerful." Confused on choice reactions. Effort impaired. "Feel sleepy." Attention limited. "Not very alert." Drowsy.	Slight dizziness. "Eyelids heavy." Very poor neuro-muscular control. Tingling sensations at extremities. "Feel slow-witted." Irritated. "Difficult to concentrate." Pugnacious. Disturbed vision-focus.	Confused. Slightly dizzy. "Feel intoxicated." Loss of neuro-muscular control. Tremors in hands, face, and legs. Mind clear but cannot execute acts. Unusual persistence. Loss of judgment. No control over hands.	Exhilarated. Improvement on reaction times. Very cheerful throughout. Impaired motor control. "Difficult to focus." Lights dim. Very amused at poor handwriting. Very slow movements. Concentration impaired.	"Trifle dizzy." Peculiar sensations in lungs and arms. Became very sleepy. Tremors in hands and legs. "Mind clear but can't move quickly or accurately." Fatigued. "Fed up and irritated."	Cheerful. "Feel slightly tight." Slightly impaired motor control. Uncontrollable laughter. Very incoordinated movements. Loss of discrimination and effort. No desire to give up.	Very warm and pleasant. Uncontrolled laughter. Noticeable fatigue in arm. Impaired vision. Sudden outbursts of laughter.	"Feel intoxicated." Marked loss of motor control. Lacking in effort and coordination. "Feel like crying." Awareness limited. Sudden shift of mood. Indifference.

included herein. One of the interesting results of this experiment was the mental retardation and confusion which persisted for at least 30 minutes after the flight had ended. A severe frontal headache also occurred after the flight and lasted for 24 hours, accompanied by unusual fatigue.



EXPLANATORY REMARKS

Control specimen of normal handwriting.

No apparent effect.

Beginning muscular incoordination.

Definite physical and mental inefficiency.

Last zero left off both 18000 and 20000—marked incoordination.

Feeling better? Evidence of false feeling of well being.

Feel good? Insight, judgment and coordination very faulty.

Mental and physical helplessness.

Improvement with few breaths of oxygen.

Last zero left off—general improvement but not completely normal.

FIGURE 4.—Effect of oxygen-want on handwriting during ascent.

b. The charts of handwriting shown in figures 4 and 5 were obtained during one of the many experiments made at the Aero Medical Research Laboratory, Airs Corps Matériel Division, Dayton, Ohio.

(1) Figure 4 shows the specimen of handwriting made during ascent, without using oxygen, to 25,000 feet, where unconsciousness became evident and where oxygen was turned on.

EXPLANATORY REMARKS	Descent from 30,000 ft. without Oxygen
Eight seconds after oxygen supply removed word "rate" misspelled. In 15 seconds complete helplessness. Unconscious after 90 seconds which lasted for 90 seconds. Recovered at 26,000 ft.	
Marked mental confusion and physical inefficiency down to 16,000 ft.	
First definite improvement.	
Gradual return to normal at about 12,000 feet. Descent from 30,000 to 10,000 ft. in 10 minutes.	

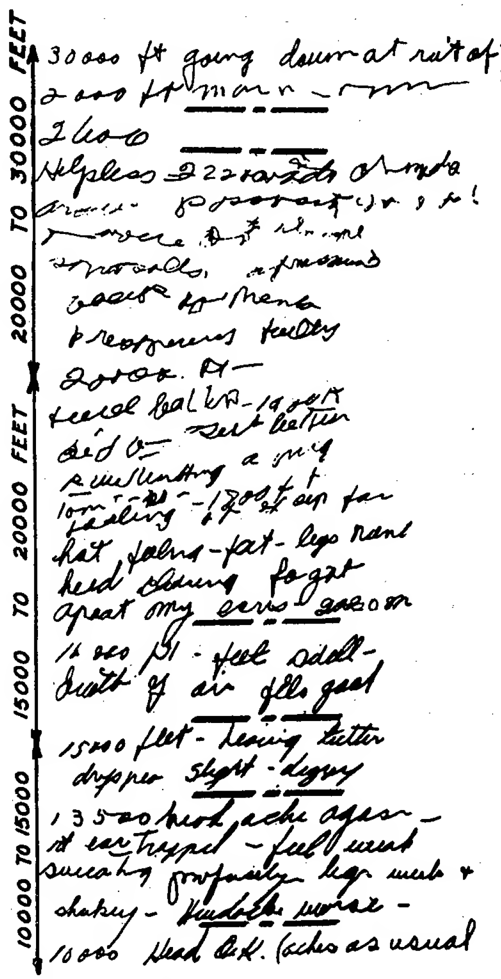


FIGURE 5.—Effect of oxygen-want on handwriting during descent.

(2) Figure 5 shows the specimen of handwriting made during descent from 30,000 feet at the rate of 2,000 feet per minute, without using oxygen. The marginal notes and scale of altitudes on the figures are explanatory.

c. The harmful physical effects and the hazards produced by flights to high altitudes without the use of oxygen until recently had not been impressed upon flying personnel. This fact is evidenced by the frequency in the past with which individuals have flown at from 15,000 to 24,000 feet on test flights and other missions, and at times for no other purpose than to see how high they could fly without feeling the effects. There is a case on record where a squadron commander was at one time seriously considering squadron close-formation training at 20,000 feet without using oxygen. The reason that such things were once done or contemplated was probably due to three principal causes:

(1) There was no organized system of instructing all flying personnel as to the dangers of oxygen-want.

(2) It was general knowledge that in laboratory tests pilots could go to from 15,000 to 20,000 feet for a short period of time without oxygen.

(3) Pilots who go to high altitudes without using oxygen are not usually conscious of their condition produced by the ill effects from oxygen-want. The foregoing factors seem to have led some individuals to adopt the erroneous impression that oxygen-want could be endured and was not harmful.

d. Anoxia affecting the pilot of an airplane may lead to errors in judgment that may be disastrous in combat or result in a crash. Likewise, the efficiency of the other members of combat crews is lowered or may be lost entirely.

e. It is obvious that flying while suffering from oxygen-want is particularly dangerous for several reasons, as all those physical and mental qualities which are so necessary for safe flying are either impaired or temporarily lost. These include visual acuity, eye muscle balance, depth perception, attentiveness, good judgment, keen intellect, alertness, and emotional stability. Not only are these important functions impaired at high altitude but the effects are not fully or immediately relieved on returning to the lower altitudes, so that no doubt many landing and other accidents have been due to the abnormal condition of the pilot upon returning from a flight during which an artificial oxygen supply was not used.

f. Experiments performed with subjects in a Link trainer, using laboratory equipment, demonstrate that exposure to high altitude conditions often results in the pilot's becoming confused and lost when he is flying "blind," due to the effects of oxygen-want (anoxia).

g. Two of the many cases on record which illustrate the temporary impairment or loss of normality due to oxygen-want are recounted herewith:

(1) During a flight at high altitude a member of a squadron lost his oxygen-tube connection and continuing the flight ran amuck among the other airplanes of the formation and escaped a crash only by the ability of the other members of the squadron to outmaneuver him. During this time he was totally unaware of his actions and believed he was doing a masterful job of flying.

(2) The second example occurred during a flight in which a pilot and passenger attempted to see how high they could go without oxygen. At about 20,000 feet the passenger noticed that the pilot had a very red sunburned neck which, as the climb continued, became very annoying to him. The sight of the red neck finally became so obnoxious to the passenger that he began to search about for a fire extinguisher or other weapon with which to kill the pilot (fixed irrational idea) and get the offending neck out of sight. Fortunately, no weapon was available and the pilot escaped probable death, although he flew at the airplane's ceiling, squashing along for a considerable time before he realized that they were unable to climb higher.

h. Anoxia, or altitude sickness, requires careful supervision by specialized medical personnel. Prolonged or repeated exposure to anoxia will reduce the airman's sense of vision and hearing and disrupt logical reasoning, coordination, and finally bring on operational fatigue, stress, or collapse.

18. Use of oxygen under pressure at extremely high altitudes.—*a.* By the use of appropriate oxygen inhalation apparatus it is now possible to ascend to 33,000 feet, with proper equipment and training, and have a normal oxygen supply in the lungs and body.

b. About 30,000 feet appears to be the upper practicable physiological limit for transport and commercial aviation because of the danger of rapidly developing unconsciousness if the personnel should remove their oxygen masks or the pressure should be lost in the pressure cabin.

c. An elevation of 37,000 feet is about the upper practicable limit that can be attempted in military aviation even with the aid of the inhalation of absolutely pure oxygen, efficient oxygen equipment, and advanced training.

d. To operate at elevations near 40,000 feet or above, oxygen must be administered under positive pressure by some means, such as a pressure suit, pressure cabin, etc. For the safety of all concerned, no aviator should at any time exceed 37,000 feet without using oxygen under pressure and without adequate equipment and training for same.

19. Types of anoxia.—*a.* Anoxia is a term used to describe oxygen lack in the body from any cause. The term "anoxemia" has the more restricted meaning of oxygen lack in the blood.

b. There are four recognized types of anoxia caused as follows:

(1) By low oxygen pressure in the inspired air.

(2) By a lack of red blood cells to carry the oxygen.

(3) By a sluggish circulation failing to get the oxygen about the body.

(4) By inability of the cells to utilize the oxygen.

Section IV

ALTITUDE TOLERANCE OR COMPENSATION AGAINST OXGYGEN-WANT

20. Altitude tolerance (endurance) against oxygen-want.—*a*. During ascent the partial pressure of oxygen progressively falls in proportion to the barometric pressure. To offset this, certain limited compensatory mechanisms of the body are activated which promote in individuals what is termed "altitude tolerance." There is some variation between different persons as to the altitude they can withstand without losing consciousness or without becoming disabled. These variations determine the degree of altitude tolerance, or endurance, of individuals.

b. A general predisposition to fainting attacks or attacks of dizziness and a special tendency toward sudden loss of consciousness when there is a lack of oxygen make a person unfit for altitude flights. The excessive use of alcohol and tobacco, particularly when combined with loss of sleep, increases considerably the effects of altitude.

21. Compensation for decreased oxygen.—*a*. Flying personnel are interested in the effects of intermittent exposures to different degrees of oxygen-want for variable periods of time. This problem is different from that arising from residence at high altitude. The effects, however, are the same in each for comparable periods of time and under like conditions.

b. It is known that persons who have resided all their lives in rarefied atmosphere at high surface altitudes do not experience mountain sickness. The resistance is brought about to a great extent by an increase in the red blood cells. It is due, in part, to actual chemical change in the blood. It may be that much of the acclimatization to high altitude consists in the habituation of the tissues to live, not on less oxygen, but on oxygen at lower pressure. In any case the oxygen

delivered to the tissues depends on the rate at which the blood is pumped through the body, as well as the amount of oxygen in the blood at any one time. The attempt of the body to make some compensating adjustment in the average person accounts for the fact that when a sudden ascent is made, the heart rate is increased even without exertion. In the acclimatized person, however, the simple expedient of pumping blood faster is not resorted to except in response to activity or work.

c. Unfortunately, the body is limited during flight in its ability to compensate for oxygen-want. This is due to the fact that the carbon dioxide accumulation in the body, and not the lack of oxygen, is the factor which determines to a great extent the breathing rate. Thus at 15,000 feet where one would expect a great increase in breathing rate (respiration) from oxygen-want, only slightly increased breathing is found, since the carbon dioxide accumulation within the body is approximately the same. The physiological effects of oxygen-want, therefore, depend upon whether compensation is complete, within altitude ranges where compensation is possible.

d. An important compensatory mechanism is an increase (forced or natural) in the depth of respiration (breathing) with very little change in rate. By this means the absorption of oxygen is somewhat increased, as a greater surface area in the lungs is made available for diffusion of oxygen into the blood by the opening up of more capillaries; the thinning of the membrane of the lungs from stretching is said to favor diffusion, and the pumping action of respiration facilitates the circulation of the blood. In some individuals this increase in breathing (pulmonary ventilation) begins at an altitude as low as 5,000 feet, while in others it increases very little up to the altitude where consciousness is lost. Those having an early respiratory response are most adaptable to rapid changes in altitude.

e. Other compensatory mechanisms are slower in developing. These are directed toward increasing the blood transportation of oxygen to the tissues when a greater number of red blood cells are put into active circulation. The circulating blood volume is increased by greater heart output and by greater venous return. The rate of blood flow is increased by elevation of the blood pressure and more rapid heart rate.

22. Time factor in altitude tolerance to oxygen-want.—*a.* The factors which influence altitude tolerance during oxygen-want have been determined both in men and in experimental animals in flight and pressure chambers, with the general conclusion that the shorter the time of ascent the higher the altitude tolerance.

(1) Altitude tolerance to oxygen-want is approximately 16 percent lower during a period of 2 hours and 33 percent lower during a period of 10 hours than it is for short periods of 15 minutes' duration.

(2) An ascent to high altitude produces a lowering of the altitude tolerance, but altitude tolerance returns to normal within from 24 to 48 hours.

(3) Daily exposures to high altitudes produce a gradual adaptation of the organism which increases the altitude tolerance for a period of 3 or 4 weeks, but this is followed by a deterioration of the organism with a final lowering of altitude tolerance.

(4) Unconsciousness at high altitude is close to the fatal point and may produce central nervous tissue damage resulting in paralysis.

b. The Aero Medical Research Laboratory conducted tests to determine the effect of repeated exposures to 12,000 feet. Altitude pressure experiments were conducted for 4 and 7 hours daily on healthy male adults. These simulated flying conditions only in respect to pressure and oxygen-want.

(1) Exposure to an altitude of 12,000 feet for 4 hours daily over a period of 27 days (less than 1 month) produced the following average effects in young, healthy male adults:

(*a*) Each exposure for 4 hours produces a concurrent mental and physical fatigue which persists for approximately 24 hours and is manifested by difficulty in mental concentration, retention, and attention over periods of time in excess of a few minutes; by sleepiness and lassitude; by errors in reasoning; and by lack of initiative.

(*b*) Repeated daily exposures produce a continuous mental and physical fatigue throughout each 24-hour period with symptoms similar to those mentioned above. In addition, nervous irritability is increased.

(2) Exposure to an altitude pressure of 12,000 feet for 7 hours daily over a period of 27 days produced results similar to those noted above but to a greater degree than for the 4-hour daily exposures, except that the subjects also developed symptoms of mountain sickness, as manifested by loss of appetite, nausea, indigestion, and dizziness.

c. During any degree of inadequate compensation to altitude, the effects of oxygen-want become accumulative, so that the same effects may be produced by a longer stay at lower altitudes as by a shorter stay at higher altitudes. The total time at anoxic levels is, therefore, of utmost importance. Also since some compensatory processes are relatively slow in developing, the rate of ascent has an effect on the reactions to high altitude.

d. Physical fitness governs the capacity of the body to supply oxygen to the tissues and also the magnitude of the oxygen debt which it

can tolerate. Therefore, physical fitness is of utmost importance in determining the tolerance to high altitude.

e. Other factors affecting altitude tolerance are: Age; emotional disturbances; the amount of exertion; the effects of food, tobacco, and alcohol; the roughness of the air; and the frequency and duration of flights.

f. Various authorities state that up to 48 hours is necessary for complete recovery from the effects of severe oxygen-want. Repetition of the experience of oxygen-want before complete recovery leads to accumulative effects resulting in a state of chronic fatigue, staleness or stress, with lowering of the altitude tolerance.

23. Danger of breathing toxic motor gases.—*a.* Carbon monoxide definitely increases the ill effects of altitude. Breathing of exhaust gases, due to the carbon monoxide which they contain, adds still further to the harm caused by the lack of oxygen and lowers the altitude tolerance because blood charged with carbon monoxide takes up less oxygen. Therefore, in an airplane the crew is endangered by the exhaust gas if it is not led away completely.

b. In an enclosed airplane the external air streaming past may produce a decreased pressure in the cabin, as compared with that without, and draw in oil fumes and gas from places that are difficult to detect. Changes in paint covering, small dents in the external walls, bullet holes, or tears by shell fragments may so influence the air currents about the airplane that even if previously free from exhaust gas the interior may accumulate a toxic carbon monoxide concentration.

c. Before constructors took precautions to guard against the dangers of the inhalation of exhaust gases, examination of the crew in several cases disclosed that even after an hour's flight there were definite evidences of exhaust gas poisoning (fatigue, dizziness, headache, nausea, and depression).

d. The poisonous action of exhaust gas depends chiefly on carbon monoxide. The proportion of this gas is least during ordinary flying when the combustion is good, greater in a throttled flight, and particularly strong when the motor is running free or idling.

e. The danger from the lead content of exhaust gas when tetraethyl gasoline is used is small in comparison with the dangers of carbon monoxide. Nevertheless, the presence of lead in the exhaust gas makes the smell more disagreeable and, in persons susceptible to such odors, may definitely increase the tendency to altitude sickness and after flight leave them without appetite.

f. Carbon monoxide has an affinity for the oxygen-carrying pigment of the blood (haemoglobin) three hundred times greater than

that of oxygen. Consequently, the symptoms of altitude sickness may occur even at sea level if the air breathed for 45 minutes contains 0.05 percent of carbon monoxide, because in this time about one-half of the haemoglobin of the blood will be united with carbon monoxide and it can no longer absorb and transport oxygen. In this connection it must also be remembered that not only the oxygen supply for the crew but also that to the motor is diminished at high altitudes, and if the motor supercharger is not working effectively the combustion in the motor becomes less complete and the content of carbon monoxide in the exhaust increases.

g. Every endeavor should be used to prevent oil vapors reaching the pilot or crew. The oils evaporated from hot, running motors produce disagreeable smells which produce nausea and increase gastric irritation.

h. Certain cooling liquids will give off noxious gases if spilled on hot manifolds or exhausts.

SECTION V

EFFECTS OF INCREASED ALTITUDE AND REDUCED ATMOSPHERIC PRESSURE UPON BODY

24. Effects of increasing altitude and decreasing atmospheric pressure upon internal gas pressures of body.—*a.* Differences in pressure between low and high altitude produce serious effects upon the body. When the pressure on the exterior surfaces of the body is decreased, the internal pressures must similarly decrease or the body will burst. The gases within the body, for instance, expand in inverse proportion to the change in atmospheric pressure (see fig. 6). During ascent the outside air pressure is lowered to a point where it finally interferes with breathing by causing the diaphragm to be pushed upward by the expansion of gases in the stomach and intestines. Hence, before or during flight it is detrimental to eat foods that will produce gases causing flatulency or belching.

b. When the gases in the stomach and intestines expand on ascent, the volume of such gas would at 18,000 feet be double and at 33,500 feet would be four times its original volume unless eliminated. This is illustrated by figure 6. The expansion naturally may cause considerable distress and interfere with respiration.

c. An important consideration in high altitude flights is an understanding of a proper diet whereby gas-producing foods are excluded. The diet for high and relatively high altitude flights should be properly prescribed by medical personnel after careful study and consideration of the many factors involved.

d. The effects of changes in atmospheric pressure are caused by a difference in pressure between the gases and fluids confined within the

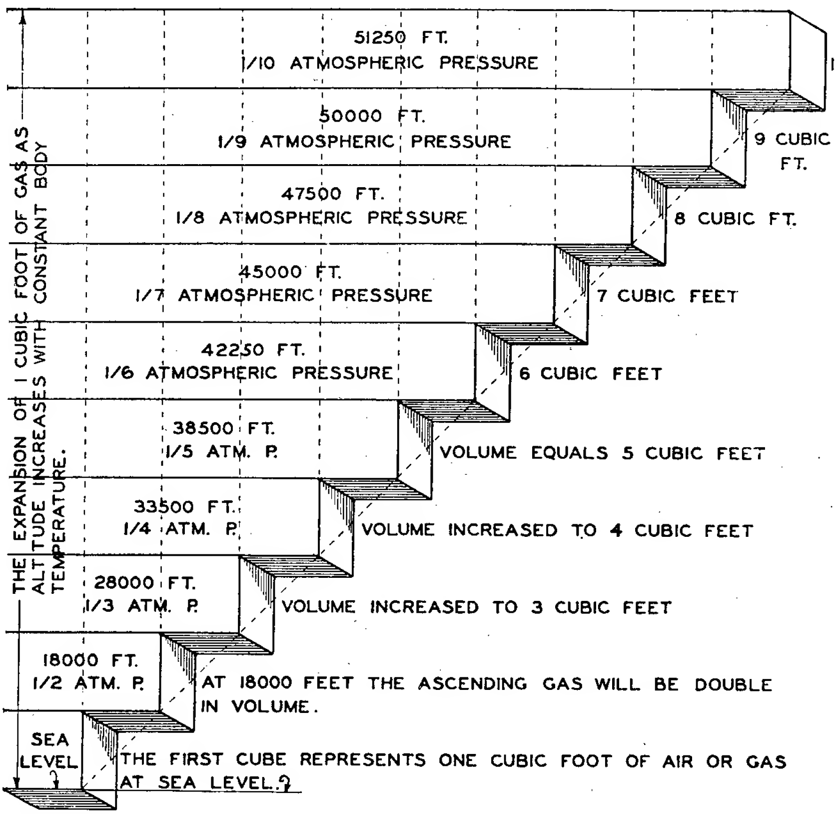


FIGURE 6.—Diagrammatic chart showing expansion of 1 cubic foot of air in rising from sea level atmospheric pressure to a value of one-tenth atmospheric pressure at 51,250 feet altitude.

body and that of the atmosphere in contact with it. In either case, air and gases cannot get in fast enough or out fast enough. The nature of these effects depends upon how the gases are confined within the body and the mechanism by which equalization of pressure is effected between the interior and the outside atmosphere.

e. Gas is found in the body both in solution and in its free state. Gas in solution occurs in the blood, spinal fluid, and all body fluids. Equalization of pressure is partly dependent upon the circulation of the blood and the gaseous interchange in the lungs.

25. Effects of low atmospheric pressure at high altitudes upon blood and other body fluids (aeroembolism).—*a.* Aeroembolism or low pressure sickness, also known as decompression sickness or the bends, is the result of decreased atmospheric pressure accompanied by the creation of bubbles in the tissues, the blood, and in other fluids of the body. Aeroembolism is caused by the evolution of bubbles, consisting of nitrogen, carbon dioxide, and water vapor, in the blood and other body liquids. If a container of water is taken to high altitudes in the atmosphere or into a low pressure chamber, gas bubbles like those in ginger ale or champagne will start to form. These bubbles begin to become evident in the water at approximately one-half atmospheric pressure, or at 18,000 feet, and are very evident before an altitude of 30,000 feet is reached. Likewise, the formation of bubbles will occur within the human body, in the blood stream and tissue fluids, and is more pronounced if the ascent to these altitudes is rapid. Champagne, ginger ale, and coca cola when bottled and capped are kept under pressure greater than that of the atmosphere. When the stoppers or bottle caps are removed the pressure is reduced and bubbles form rapidly; carbon dioxide or other gases which were held in solution are thrown off to the lower atmospheric pressure. This is somewhat similar to the action which takes place within the blood and other liquids of the body when atmospheric pressures are reduced upon ascent to high altitudes.

b. Aeroembolism usually affects the average aviator at altitudes above 30,000 feet. Certain individuals can go to 40,000 feet repeatedly and get no symptoms. Individuals who have symptoms between 30,000 and 40,000 feet tend to have about the same symptoms on subsequent flights and these symptoms also tend to occur at nearly the same altitude. Most symptoms which occur are trivial although a small percentage of aviators will be incapacitated.

c. Aerial missions which require military flyers to remain for considerable periods of time in or near the stratosphere have made it imperative that special consideration be given to the effects of operating under such extremely low atmospheric pressure.

d. War experiences in Europe have shown that serious conditions develop due to low atmospheric pressure, even while using pure oxygen, at altitudes between 30,000 and 37,000 feet. Some airmen are affected at lower altitudes. The height of lowest susceptibility is of

importance and is the subject of present-day research, as the limit of susceptibility of the one member of a combat crew possessing susceptibility at the lowest altitude restricts the "ceiling" of the airplane to that altitude for the performance of a mission at maximum efficiency. Therefore, susceptibility limits should be tabulated for all flying personnel and should have some bearing upon the selection of combat crews.

e. When the flyer enters the stratosphere he has usually passed rapidly from normal surface atmospheric pressure to about one-fourth

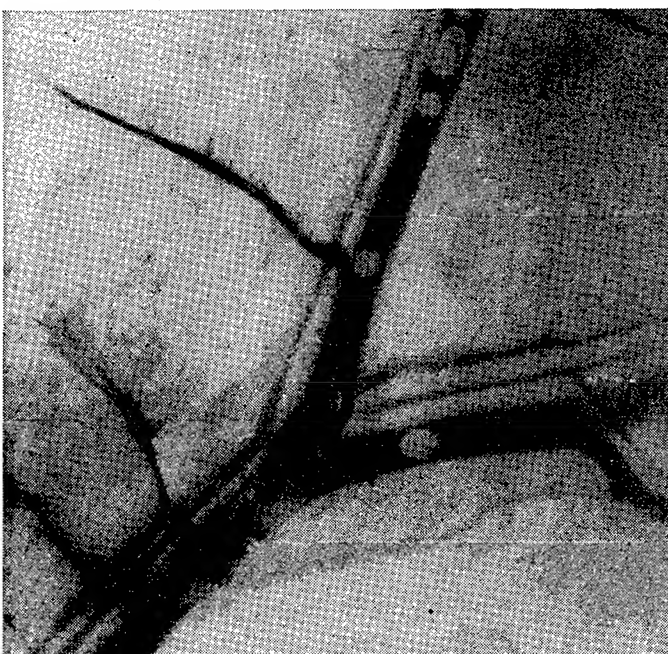


FIGURE 7.—Nitrogen bubbles in blood of goat after ascent to very high altitude.

atmospheric pressure where the danger of aeroembolism or bends is probable. Either a rapid rate of climb or a prolonged stay will cause nitrogen bubbles to form in the blood at altitude pressures of about 30,000 feet. Figure 7 shows the bubble formations in the blood vessels of a goat which was taken to very high altitude. This photograph was made upon return to the earth's surface. Therefore, the bubbles shown are much smaller in the photograph than they were at the maximum altitude reached. Figure 8 shows the bubble formations in the brain of the same goat. If the ascent is very gradual up to 30,000 or 35,000 feet, with slowly diminishing pressure, these bubbles may not become

evident for a short period of time. Otherwise, the airman will suffer almost unendurable pain. In such case, the suffering may be sufficient to disable members of the combat crew and make them easy victims of the enemy, who, by scientific knowledge and methods, may be free from the effects of altitude.

f. From observations made in 250 cases it was found that decompression sickness rarely occurred below 30,000 feet. But even with

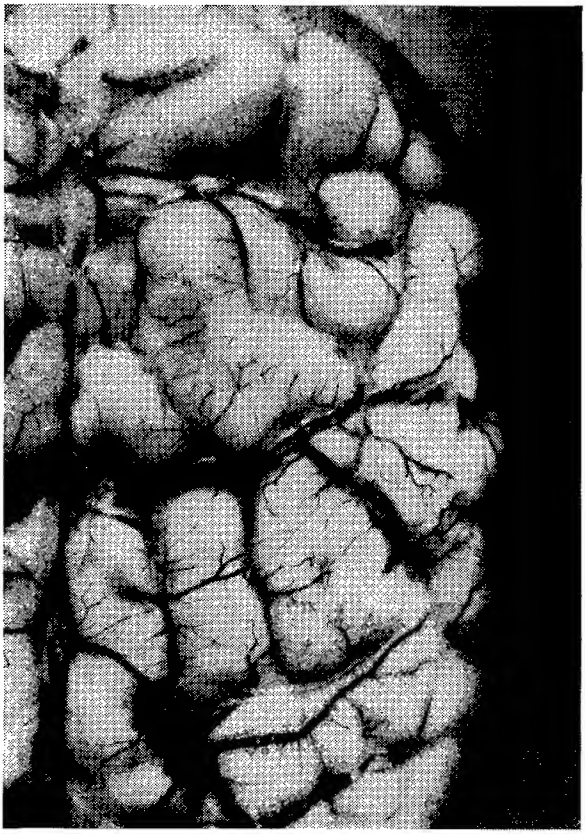


FIGURE 8.—Nitrogen bubbles in brain of goat after ascent to very high altitude.

slow rates of ascent the effects were very positive upon reaching an altitude of 35,000 feet. Even with the slow rate of ascending to 35,000 feet in a period of 1 hour, decompression sickness was experienced in a number of individuals tested in such a degree as to be completely incapacitating. Tests conducted in this country indicate that a considerable percentage are affected seriously at this altitude. The symptoms of aeroembolism may take some time to appear, and unless an

hour or more is spent in the stratosphere above 30,000 feet the symptoms may not develop in all cases.

g. There is variation in occurrence of low pressure sickness in different individuals and in the same individuals on different occasions.

h. The initial symptoms of aeroembolism (decompression sickness) may be as follows:

(1) Tingling and itching of the skin.

(2) Severe pain in muscles and joints, particularly in the location of any scar tissues.

(3) Visual and auditory impairment.

(4) Collapse of circulation.

(5) Profuse sweating.

(6) Failure of the pulse.

(7) Unconsciousness.

i. Usually during rapid descent where oxygen is used continually, recovery begins quickly below 20,000 feet, but headache, visual and other disturbances may remain for several hours after return to the earth's surface.

j. A partial preventive of the symptoms and effects of low pressure sickness at high altitude may be attained by the standard diving procedure of breathing oxygen while taking exercise before ascent. Experiments so far conducted indicate that some of the muscular pain can be prevented in that manner, but the effects which appear to be of nervous origin still occur with prolonged flight at high altitude above 35,000 feet. Experiments have shown that this procedure is effective for flights of moderate duration at altitudes below or between 30,000 and 35,000 feet by delaying the onset of symptoms.

k. The removal of nitrogen dissolved in the body tissues can be accomplished by the inhalation of pure oxygen while on the surface or while in flight at altitudes up to 18,000 feet. This will, if continued long enough, eliminate the symptoms incident to aeroembolism.

l. Although various methods of denitrogenation or decompression have been employed, using oxygen or helium oxygen mixtures, there is little evidence that they other than delay symptoms unless continued for long periods. This long period of denitrogenation is, in general, unsatisfactory for military operations.

m. Up to an altitude of about 18,000 feet, rapid ascents at a maximum rate of climb do not appear to produce aeroembolism. Rapid ascents to altitudes between 20,000 and 30,000 feet will produce positive bubble formation in the blood and body liquids, although in most cases this will not be accompanied by severe symptoms. Milder symptoms may appear between 20,000 and 30,000 feet if the stay is pro-

longed for 3 or 4 hours. Ascent at maximum rate of climb to altitudes between 30,000 and 37,000 feet will in most cases produce symptoms as enumerated in *h* above unless decompression is accomplished prior to ascent. Tests have been conducted which indicate that the altitude tolerance against low pressure can be increased by 2,000 to 5,000 feet in altitude by proper decompression before the ascent is made; also that the duration of time at high altitude can be extended by this method.

n. One of the most important treatments for aeroembolism is immediate recompression upon the appearance of the first symptoms. This can be accomplished by immediate descent to lower altitude. If treatment or corrective measures are not taken, immediate disability will be the probable result. The time factor is of importance. Upon rapid descent, symptoms of aeroembolism may disappear before the ground level is reached, but in severe cases immediate treatment and recompression, combined with the inhalation of pure oxygen, may be required.

o. The following summary suggests some of the remedial and preventive actions against aeroembolism:

(1) The removal of nitrogen gas from the tissues of the body may reduce the effects of aeroembolism and enable ascents at the maximum rate of climb to altitudes of 35,000 feet and permit remaining there for longer periods of duration.

(2) It is possible to free the blood from nitrogen during flight while using pure oxygen at altitudes around 18,000 feet almost as effectively as at sea level.

(3) It is highly essential that steps be taken to eliminate the nitrogen from the body before rapid ascents are made to prevent the effects of aeroembolism if considerable time is to be spent at high altitudes.

(4) To prevent disability after experiencing the effects of aeroembolism the best treatment is an immediate return to lower altitudes or to the surface where treatment should be made immediately.

(5) Individual susceptibility to the dangers of low atmospheric pressures is an important factor in the selection of combat crews. This can be determined in flight but preferably in decompression chambers.

26. Other effects of low atmospheric pressure at high altitudes.—*a.* Free gas is found in the body in the middle ear, nasal accessory sinuses, and certain serous spaces. Characteristic symptoms may be produced in each of these, especially during ascent, by the relatively greater pressure or volume of air within them resulting from interference with proper exchange between the interior and exterior of the body. Alterations of the voice and loss of efficiency

of the respiratory protective mechanisms, such as coughing and sneezing, are the first noticeable effects likely to occur.

b. Another effect of decrease in atmospheric pressure is the necessity for adjustment of the middle ear mechanism, where difficulty in clearing the passages is frequently felt. When great change of pressure takes place, the air in the middle ear and sinuses must be able to expand without hinderance and also, above all, be able to condense again. Otherwise, there is, with respect to the outer air, a considerable difference of pressure which causes severe ear pains and frontal headaches. The best remedy found to date for this is to make repeated swallowing and yawning movements or force air behind the membrane while the nose is held, because this is the best way to open at will the passageway leading from the middle ear to the throat.

c. Due to the danger from suppuration of the middle ear or of the sinuses, persons suffering from pronounced throat, nasal, or sinus catarrh are strongly advised against making flights involving great changes in altitude. An interesting observation noted on experimental high altitude flights was that at altitudes above 30,000 feet there was great difficulty in clearing the bronchial tubes of mucous. In a normal cough the lungs are filled with air, the throat closed, and a high positive pressure built up in the lungs, which, when suddenly released, forces the air through the bronchial tubes in a strong blast carrying mucous with it, thus removing the cause of the cough. This could not be done at high altitude, probably due to the fact that the density of the air was not sufficient to carry the relatively heavy mucous with it. This would indicate that extremely high altitudes should be avoided by those with bronchial irritations or inflammations because of the continuous unproductive coughing which would result.

d. Much progress has been made to develop equipment in the form of pressure suits, pressure cabins, and pressure compartments which will enable normal atmospheric pressure to be maintained during flight. These developments, although still in the experimental stage, have given initial successes sufficient to expect that in the future equipment will be developed which will enable the airman successfully to reach the higher limits of the stratosphere and at the same time maintain his combat efficiency.

27. Deficiency of hearing at high altitudes.—*a.* At high altitudes, due to low atmospheric density, it is reasonable to expect that conversation between members of combat crews over the interphone and communication by radio will be affected.

b. When flying at altitudes in or near the stratosphere the sound waves produced by the voice will not be transmitted with the same energy as at low altitudes. Therefore, a diminished force upon the

transmitter would normally produce a weakened signal. In the same manner, the low atmospheric density would affect the transmission between the receiver and the ear.

SECTION VI

EFFECTS OF LOW TEMPERATURES (COLD), ESPECIALLY AT HIGH ALTITUDES

28. Effects of cold.—The physical suffering and resultant lowering of efficiency representing effects from exposure to cold temperatures are more familiar to human beings than are the effects of oxygen-want and of low pressure. Nevertheless, the importance of the detrimental effect of low temperatures upon personnel performing flying missions is so great as to warrant separate study and remedial or preventive action by all flying personnel.

a. Flights from relatively warm temperatures at the surface to high altitudes expose the body to sudden and extreme changes in temperatures which call for bodily compensations of unusual degree and promptness. The average atmospheric temperature decrease with increase in altitude is shown in figure 2 and table I.

b. With increasing heights above sea level the temperature of the air falls an average of 1° C. for every 500 feet of elevation to the stratosphere average level at 35,000 feet. (See fig. 2 and table I.) Above this the air temperature is almost uniform throughout the year varying only about 10° C., from −50° to −60° C.

c. In studying the problems of low temperatures (cold), it is important to consider the factors which enter into heat losses from the body. The most important of these are listed as follows:

(1) Radiation.
(2) Conduction.
(3) Convection.
(4) Evaporation.
(5) Respiration.

d. When cold air or pure oxygen is inhaled it absorbs energy, as it is usually warmed up to about 97° F. (36° C.) while within the lungs. When the air or oxygen is exhaled it carries a certain amount of heat energy and vapor with it. Thermometers designed specially for read-

ing body temperatures are nearly always calibrated in degrees Fahrenheit (° F.). Therefore both values are given in this case.

e. Due to the balance between the heat gained and heat losses of the body at about 60° F. (15° C.), the environmental temperature should be kept at about 60° F. 15° C.) for comfort. The heat losses from the

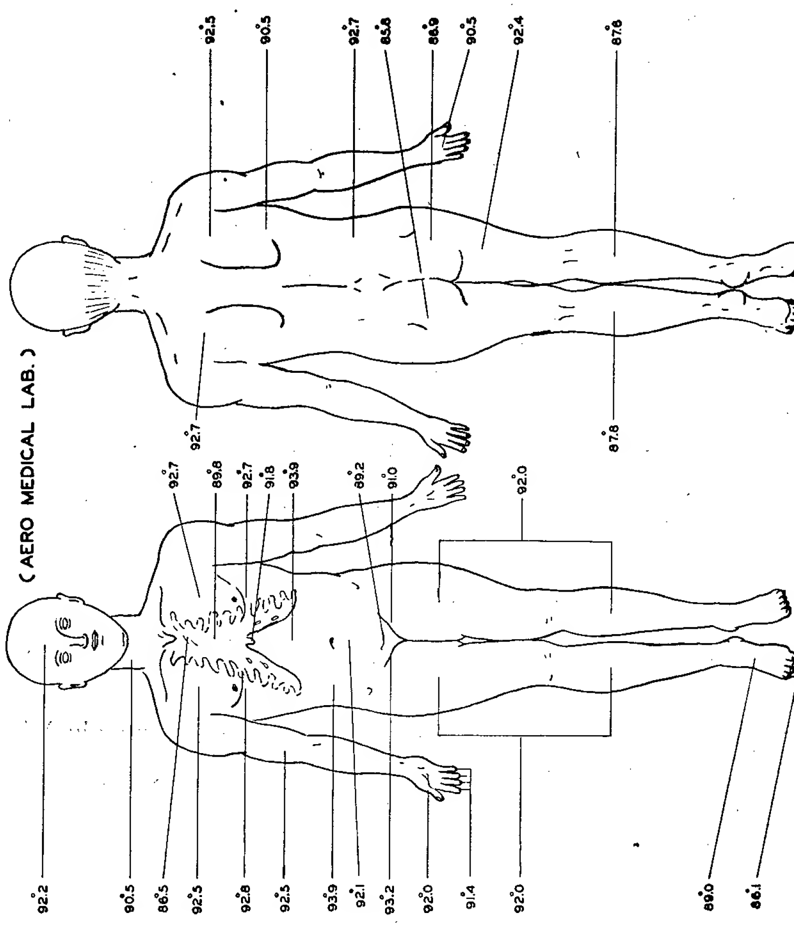


FIGURE 9.—Variation of skin temperature in different parts of body under customary indoor winter clothing (room temperature, 72° F.)

body are rapid at temperatures below 60° F. (15° C.). The temperature values in figure 9 are therefore given in degrees Fahrenheit.

f. The temperature control mechanism of the body lies in the brain and keeps the heat losses and heat gains in exact balance by chemical and muscular action. The temperature conditions of the skin, as shown in figure 9, are transmitted to the brain heat control apparatus.

g. Work or exercise causes the production of heat to go up. Relaxation or sleep reduces the required chemical action necessary within the body to maintain normal heat energy.

h. Extreme cold at high altitudes will cause sleepiness, and under extreme conditions if relaxed one may go to sleep.

i. Warm food and hot drinks enable the body rapidly to gain required heat energy and are important during operations at low temperatures.

j. The interior heating of enclosed airplanes has helped greatly to solve the problem of low atmospheric temperatures during winter, also at high altitudes throughout the year. However, this has not eliminated the necessity for the combat crew wearing warm flying clothing when posted at their various combat stations. There are two general methods of artificially heating airplanes. One method uses heat collected from around the exhaust and conducted to the cabin. This may be dangerous if there is a leakage of carbon monoxide, as explained in paragraph 23. Another method is to heat the cabin by means of steam heaters which derive their source of heat from a tank of hot water heated by the engine exhaust. This is the better method from the standpoint of safety.

k. It is within the sphere of the engineers to control, remedy, and prevent the exposure to uncomfortable and hazardous temperatures. If an aviator is not protected from cold then he must try to protect himself by shivering or exercising. Flights at 30,000 feet or above require protection against cold of tremendous severity (−40° C. to −60° C.). In the Finnish campaign, flying was apparently carried out with ground temperature of −40° C. Engineers have met considerable success in solving the problems of maintaining the mechanical equipment effective at these temperatures, but have not yet completely solved the problem of maintaining the efficiency of the human machine at these temperatures. A chilled human being is not an efficient fighter.

l. The symptoms of exposure to cold are as follows: There occurs first a sensation of chilling, followed by the reaction of "goose pimples" and pallor of the skin. If the aviator has sufficient protection, the reaction stops here; otherwise, chilling is more accentuated. There is stiffness of the extremities, numbness, and finally a tendency to sleep. This fall of temperature necessarily stimulates body heat production (metabolism), thereby increasing the demand for oxygen.

m. Heat production is varied by increasing or decreasing oxidation of foodstuffs, such as carbohydrates, fats, and proteins. It is voluntarily controlled to some extent by ingestion of food and by muscular

exercise which are attended by a marked liberation of heat. Heat production, however, is mainly under involuntary control through special centers controlling muscular metabolism. Under the influence of extreme cold increased oxidation occurs, which is a result of muscular contractions (shivering).

n. In cold weather the body heat is augmented by the use of clothing, which is most useful in decreasing heat loss by radiation, conduction, and convection.

o. Heat loss is controlled mainly by reflex control through vasomotor nerves and nerves controlling perspiration. The amount of blood brought to or in contact with the skin, where it loses its heat by conduction and radiation to the outside air, is diminished; also the amount of sweat poured out upon the skin is decreased, thus diminishing loss by evaporation. Insensible perspiration persists under all conditions. Therefore, heat loss through evaporation cannot be entirely eliminated. For example, when cold air strikes the skin it stimulates the nerve centers which control the fibers of the skin, thus causing a constriction of the small blood vessels at or near the skin surfaces and producing less exposure of blood and a consequent heat conservation. Young men possess rapid and adequate reactions to cold, while older men with less power of response are far more sensitive to low temperatures.

p. The effects of cold (low temperatures) upon a tactical mission will influence the use of controls by hands and feet, the handling and reading of maps, the reading of airplane and navigation instruments, the adjustment of gear and equipment, and a perception of the environment.

q. The weight and bulk required of winter flying clothes to insure adequate comfort and protection hinder the freedom and ease of movement and consequently contribute to fatigue.

r. As a service-type airplane can attain its ceiling in one hour's time or less, combat crews may be exposed to relatively rapid and extreme changes in temperature.

29. Flying clothing for winter or high altitudes.—*a.* After much experimental work and research, winter flying clothing still remains an admitted burden to personnel and not completely effective for protection against the low temperatures that may be encountered. This clothing adds several pounds' weight and considerable bulk to the aviator. There is also a definite restriction of necessary movement especially in those parts of the body which should remain unhindered, namely: the fingers, hands, arms, shoulders, and neck. It is obvious that with heavy gloves, small switches, dials, gun triggers, etc., are operated with difficulty, if at all, and that a fur collar tightly buttoned

about the neck is a positive bar to looking rearward without turning the whole body. The weight and efficiency of flying clothing for low temperature operations have been greatly improved by electrical heating.

b. Due to the possibility of failure, neither the exhaust heating of enclosed airplanes nor electrically heated flying suits are positive pro-

FIGURE 10.—Electrically heated suit for wear under intermediate flying clothing.

tection for extremely low temperatures of high altitudes where combat missions must be conducted. The failure of artificial heating may produce such pain as to be disastrous during a long mission to and from or while over enemy territory. Great suffering on such missions has been recorded. These and other considerations make the development and use of warm flying clothing a necessity. (See figs. 10 and 11.) However, it is desirable that each enclosed combat air-

plane be equipped with a heater capable of maintaining a temperature of +5° C. while flying in an atmospheric temperature of −40° C.

c. The wearing of bulky flying clothing, the loss in body heat energy, the malfunction of personnel equipment, the fatigue factors, and detrimental physiological and psychological reactions are the principal causes of efficiency loss due to cold temperatures.

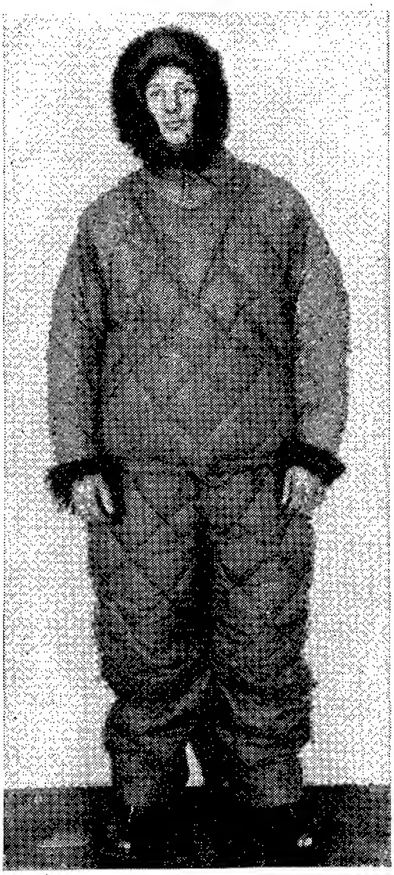


FIGURE 11.—Down-filled Alaskan parka and trousers for cold climates; suitable for ground crews.

d. During high flights it is extremely important to prevent undue loss of heat by adequate clothing, because if the body becomes cold, shivering takes place as a means of producing more heat and this entails a greatly increased intake of oxygen. Shivering is always an indication that the body can no longer be kept warm by decreasing the heat loss by constricting the skin vessels and that increased heat

production must be provided through shivering, with its attendant increase in oxygen consumption. A lack of oxygen decreases the warmth, particularly of the hands and feet, and hence the breathing of oxygen above 12,000 feet is also useful to offset the effects of cold. Therefore, every flyer going to high altitudes, even in summer, and every flyer in winter must be protected by special clothing or heated cabin against undue loss of heat and frost bite.

e. The warming of the body is dependent upon—

(1) Body metabolism.

(2) Blood flow to the skin which is regulated involuntarily by the nerves.

(3) Atmospheric temperature and the heat from the sun, also the movement and moisture of the surrounding air.

(4) Protection provided by clothing.

f. In an enclosed cabin airplane, protected by glass or some transparent material, the warming effect of the sun's rays may be appreciable.

g. The water vapor content of the air decreases rapidly with falling temperatures so that the air at −18° C. or lower contains only a small quantity of moisture. Therefore, one may feel less cold with a temperature about freezing on dry frosty days than on damper days.

h. The materials most suitable for flying clothes are those which contain much air in their interstices, such as knitted materials and fur, since the ability to retain heat and protect against cold depends chiefly on the air enclosed in the material and beneath it, as air *at rest* is a very poor conductor of heat.

(1) The outer layer of the clothing must be windproof but permeable to water vapor so that the water vapor produced by sweating may be evaporated, because moist clothing is a much better conductor of heat and therefore a poor protection against cold. As a wind resistant but permeable outer coat, the "English leather" has been valuable. Also true leather is wind resistant and permeable. Naturally, the underclothing must be permeable to water vapor. Rubber clothes are therefore to be avoided for flyers. The underclothes must be able to absorb large amounts of perspiration, as in summer before high flights much moisture will be secreted.

(2) For protection against cold, two garments are better than one even though the total thickness is less than one heavy piece. Clothing should not fit tightly and there should be no orifices through which outside air can penetrate. Winter flying suits should be made so they can be adjusted snugly at the collar, wrists, and ankles.

i. For the feet two pairs of loosely fitting stockings within the boots are recommended. Fur boots must also fit loosely over the shoes, and

it is an advantage if within the overboots there is a thick cork sole, in order to decrease the transmission of cold from the foot control.

j. During flight in severe cold, the flyer should from time to time feel his face, so as to ascertain whether it is properly protected, and notice whether any part has lost its sensation by frostbite. Such places must be rubbed thoroughly at once in order to increase the blood flow. If frostbites are discovered after landing, they should be treated at once, and in no case should they be thawed with warm water or before a fire. The physician should at once be informed, as frostbitten areas have a greatly lowered resistance to infection. While flying, frostbites may be prevented by smearing the face and hands with vaseline, cold cream, or similar protective preparations.

30. Heated flying clothing.—*a.* If electrically heated gloves are available, one can do without the heavy mittens. If the hands and feet alone are warmed electrically, they must not be warmed too much, as otherwise there will be a marked dilation of the skin vessels of the body also, and consequently a great loss of heat. The flyer is deceived by the feeling of warmth that an increased blood flow produces. Heating to the point which will cause sweating should be avoided at all times.

b. Figures 12 and 13 show experimental electrically heated flying suits which provide warmth with the minimum of weight. These electrically heated suits are worn underneath regular flying clothes or coveralls, as illustrated in figures 10 and 14. The electrically heated clothing as shown weighs 7 pounds complete and is designed to maintain comfort while flying in atmospheric temperatures as low as −60° C. It is designed primarily for fighter pilots and combat crews who are required to fly at high altitudes near or in the stratosphere. The combined use of the electrically heated suit, boots, and gloves makes cockpit heaters unnecessary, thus eliminating fogging and frosting on the inside of the windows or windshields of the airplane.

c. It is advantageous for long flights at low temperature to wear a suit electrically heated so that all parts of the body will be kept warm.

31. Masks and goggles.—*a.* Colored goggles which function satisfactorily under normal conditions tend to fog above 0° C. and to frost below 0° C. This tendency is markedly increased by the use of a face mask.

b. Face masks and goggles may be worn for protection against the sun's rays or against low temperatures. The face mask must not constrict the visual field, feel uncomfortable, or tend to produce fogging or frosting of the goggles.

32. Physiological effects of cold.—*a.* At about −15° C. cabin temperature, with winter flying clothing (not electrically heated), the personnel begin to suffer from cold. The hands and feet are the first parts affected, followed usually by the back, chest, abdomen, and legs, in order.

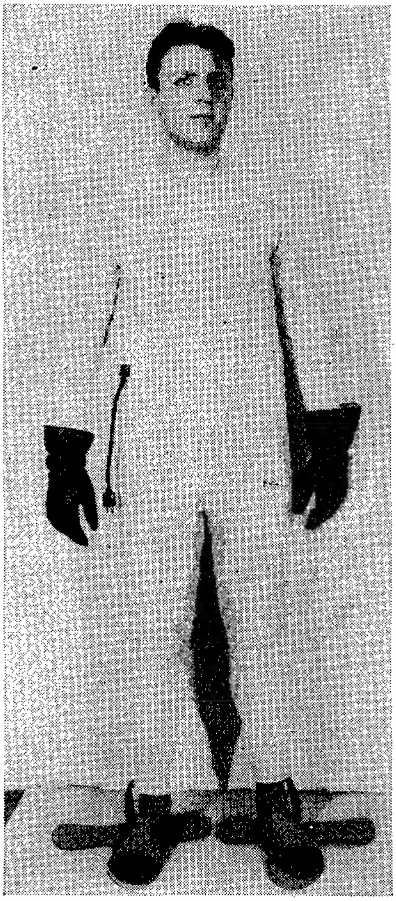


FIGURE 12.—Electrically heated suit for wear underneath regular flying clothes or coveralls.

(1) At first there are chilly sensations accompanied by increased metabolism and muscular restlessness. The chilly sensations change to discomfort, and the acuity of touch sensations and muscular reactions is dulled.

(2) As the cold increases, there is numbing of the parts of the body, producing clumsiness of movements. The muscles assume a state of mild tonic contraction which further hampers and restricts free move-

ment. Discomfort changes to pain and generalized shivering develops. Voluntary muscular movement becomes sluggish, and finally tissue destruction and death may occur at extremely low temperatures without artificial heat supply.

b. Cold, by increasing the oxidation processes in the body, increases the consumption of oxygen and hence must be avoided.

FIGURE 13.—Electrically heated suit of different model.

33. Psychological effects of cold.—The emotional state is affected indirectly by several factors.

a. The confidence of some airmen is affected while wearing winter flying clothing, being conscious of the fact that they are not then able properly to maneuver the airplane, operate equipment, or escape by parachute in an emergency.

b. The constriction, restraining, discomfort, and weight of the added equipment serve as a constant source of annoyance and detract attention from the mission at hand and contribute to fatigue.

c. The most serious effect, however, is from the psychic reactions to physical discomfort. As the cold increases, the psychic reaction

FIGURE 14.—Experimental electrically heated suit protected by coveralls, providing protection with minimum of weight.

keeps pace with the physiological. As cold increases and physical coldness progresses, the results are progressive mental distress, loss of morale, indifference or distaste for the mission, a tendency to panic, and finally a stupor which may result in freezing and death.

d. Modern, lightweight, electrically heated flying clothing eliminates the causes of many of the psychological effects above mentioned.

SECTION VII

USE OF ARTIFICIAL OXYGEN SUPPLY AND EQUIPMENT

34. Factors which determine quantity of oxygen required.—*a.* As the oxygen pressure is decreased with altitude, it becomes necessary to supply the necessary oxygen by artificial means. The quantity of this additional oxygen which must be added to the atmosphere that is breathed depends upon several factors as follows:

(1) Altitude attained.
(2) Duration of flight at that altitude.
(3) Physical effort performed.
(4) Altitude tolerance of the individual.
(5) Type of equipment used.
(6) Miscellaneous factors.

b. Proper use of oxygen will prevent, up to 35,000 or 37,000 feet, serious impoverishment of the blood in oxygen. Above 37,000 feet altitude the atmospheric pressure has become so reduced that pure oxygen supply alone no longer safely suffices for the body, and hence above this altitude the lack of oxygen should be remedied by such means as a pressure suit or a pressure cabin.

c. When pure oxygen is not used, the percentage of oxygen necessary in the inspired air increases more rapidly than the pressure decreases with altitude. The percentage of oxygen required in the inspired air at various altitudes and the effect of physical activity on the amount of oxygen required will vary slightly with different persons.

d. An individual moving about in an airplane and doing light work will require approximately twice the amount of oxygen as when seated quietly.

e. While using oxygen at lower altitudes the amount of oxygen added to the inspired air must be varied according to the amount of air inspired in order to keep the oxygen supply constant.

f. At high altitudes pure oxygen must be used. The administration of oxygen, when needed, should be continuous since there is no storage of oxygen in the body, except a small amount in the lungs and blood which is normally expended within approximately 40 seconds.

g. Above 33,000 feet the total atmospheric pressure is not sufficiently great to enable one to maintain a normal oxygen pressure in the alveoli even when breathing pure oxygen, and the body must consequently suffer from anoxia. At 40,000 feet the critical oxygen pressure value in the lungs is reached. Above this altitude the body suffers from severe anoxia even when breathing pure oxygen, and unconsciousness would result at about 46,000 feet. Death would follow a prolonged exposure to higher altitudes.

35. Oxygen equipment.—*a.* Oxygen equipment in aircraft is used to supply flight personnel with the necessary oxygen to make up oxygen deficiency in the atmosphere at high and relatively high altitudes. In all but exceptional cases, individual instruments for the regulation of supply are provided for each person participating in the flight, and the systems have a flexibility in that two users may be supplied from a common source or, in the case of extended flights at high altitudes, two cylinders may be used to supply one person.

b. Although the quantity of equipment varies with the particular airplane, the basic units in aircraft installations include—

(1) Supply cylinders.
(2) Regulator.
(3) Tubing and manifold connections.
(4) Mouthpiece or mask.

c. The current type oxygen regulator is used to control accurately the supply of oxygen needed by personnel. The instrument for use with compressed oxygen is manually operated and incorporates a sensitive flow-metering device combined with an accurate indicator.

d. Oxygen cylinders are stored in a cool, dry place and away from any oil or grease. A mixture of litharge (red lead oxide) and glycerin is used for sealing the threads at connections. Oil and grease under no circumstances are to be applied on any connections, packings, valves, gages, or other oxygen equipment. Failure to observe this precaution may result in an explosion. Castile soap may be used on the threads of the needle valve in case lubrication is required. Figure 15 illustrates the storage capacity of different types of cylinders in values of hours and altitude.

e. A very important consideration is the fact that different methods of oxygen administration vary in their efficiency. The only satisfactory means of determining the amount of oxygen required during the use of any particular type of oxygen equipment is to determine experimentally the flow necessary to give a normal value to the partial pressure of oxygen in the lungs.

f. Oxygen mask effectiveness is determined by ascertaining the minimum rate of flow of oxygen required to maintain a normal oxygen concentration in the lungs. During the period of consumption of oxygen by the tube and pipestem method, the normal individual usually expires from one-half to two-thirds of the time, which means that from

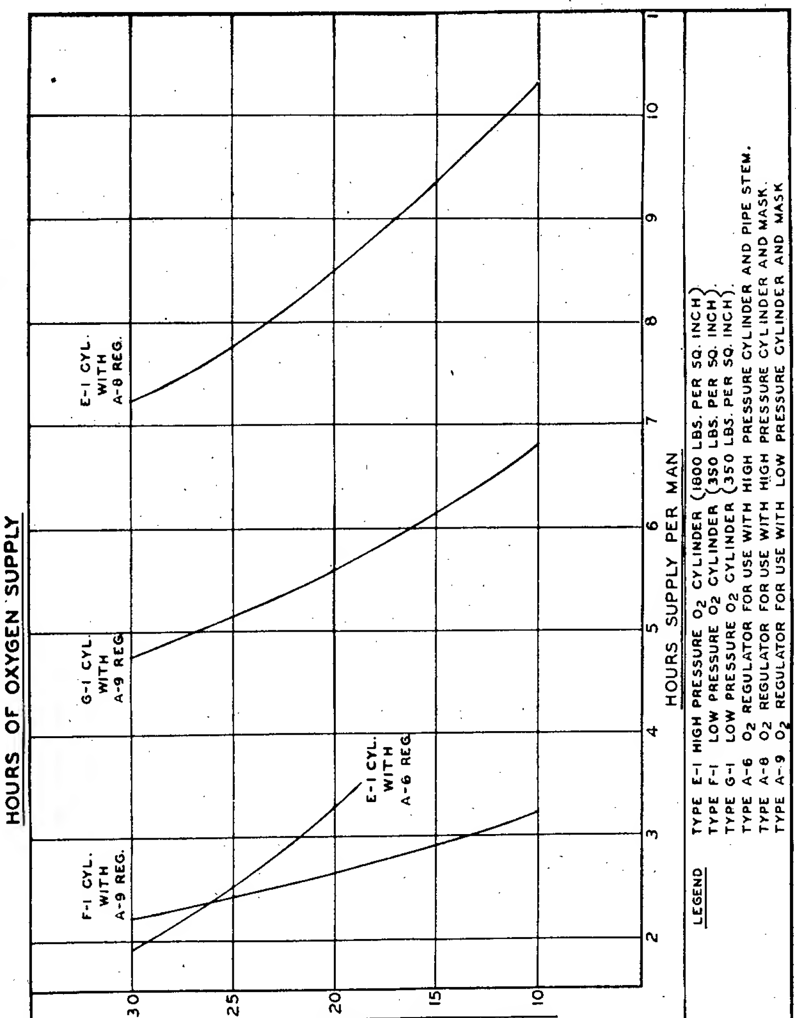


FIGURE 15.—Chart showing capacity of oxygen cylinders.

one-half to two-thirds of the oxygen is lost or wasted. Also where this method is used there is considerable difficulty in conversing with other members of the crew or over the radio. With the new respiration apparatus, and others being developed, these difficulties can be overcome.

g. New types of inhalation apparatus, using approximately one-fourth of the amount of oxygen expended by older types of apparatus, have been designed to effect the efficient and comfortable administration of oxygen to pilots and passengers. Tests carried out on this new apparatus include repeated flights at high altitudes and experiments in low-pressure chambers. The results of investigation show that the mask with the reservoir is efficient and satisfactory under certain conditions, requiring only 1.75 liters of oxygen per minute at 20,000 feet.

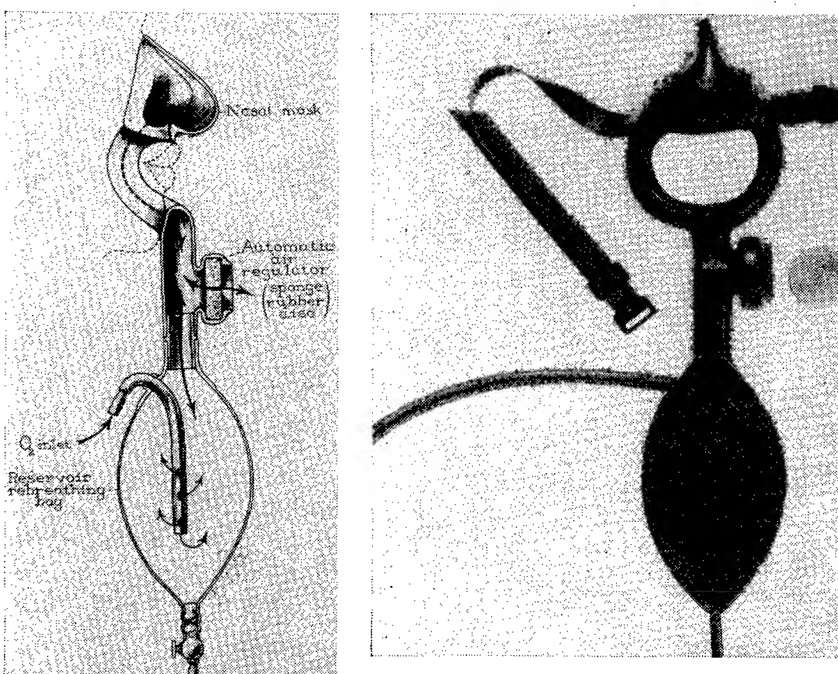


FIGURE 16.—Oxygen respiration apparatus.

h. The method of expressing volume at S. T. P. D. (standard temperature, pressure, density) is of particular value to the supply officer in order that he may readily calculate the amount of oxygen he must supply for a trip of given duration and at a given altitude; it also permits calculations of the amount which may be needed during possible variations of the original schedule. A slight excess delivered will do no harm, but a slight insufficiency must be avoided.

i. It is well to call the attention of the users as well as the manufacturers to the fact that barometric changes influence the rate of flow obtained from a given setting of the reducing valve or regulator.

j. For military aviation, the type A-8 mask shown in figure 17 is standard. In order to be able to use the radio microphone efficiently, a little turret was constructed directly opposite the mouth to hold the sponge rubber disk and against which the microphone may be closely applied. There is little interference with the transmission of sound waves if the sponge rubber automatic air regulator is placed in a specially constructed groove at the outer end of the turret; in fact increased efficiency is obtained in part by exclusion of extraneous noise. The possibility of the moisture in the breath freezing in the sponge rubber disk is a danger.

FIGURE 17.—A-8 type of oxygen mask.

36. Accidental or other interruption of oxygen supply.—*a.* Consideration must be taken of the seriousness of an interruption of the oxygen supply at various altitudes. This interruption could be produced by a variety of causes, among which are—

(1) Freezing of the oxygen regulator valve.
(2) Malfunctioning of the regulator.
(3) Exhaustion of supply.
(4) Removal of the mask for various reasons.
(5) Rupture of the hose connections.
(6) Unfamiliarity with the proper use of the equipment.
(7) Puncture by enemy bullet or shell fragment.

(8) Formation of ice upon and around the oxygen mask due to vapor in the breath.

(9) Other miscellaneous causes.

b. While flying at high altitudes great danger may develop by the failure of oxygen apparatus to function properly, or after the consumption of the available supply, as it might be impossible to descend

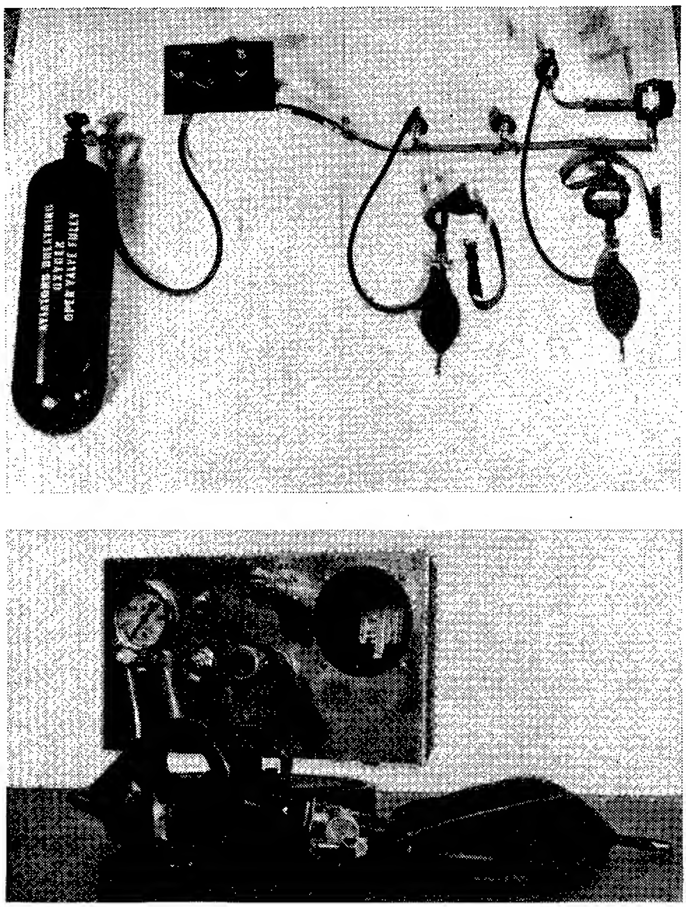


FIGURE 18.—Oxygen equipment installation.

quickly enough to low altitudes to prevent unconsciousness and perhaps death.

37. Use of oxygen and oxygen equipment.—*a.* Commanding officers are responsible that all personnel who are required to install, maintain, or use oxygen equipment read and understand the contents of the Technical Orders in effect.

b. During air combat the use of efficient apparatus and the provision of adequate oxygen and training in its use affect moral and mental superiority over the opponent.

c. The higher one is to fly the more important it is to see that the apparatus is in good order. As the altitude increases there is a decrease in the time elapsing between the interruption of oxygen breathing and the appearance of symptoms of serious altitude sickness. Following an interruption of supply at 20,000 feet, unconsciousness would occur in a relatively short period of time. At altitudes below 18,000 feet the time still available for remedial measures (removal of the trouble or descent) amounts to several minutes.

d. At 25,000 feet and with breathing of atmospheric air, loss of consciousness will set in within a few minutes. At higher altitudes, the time limit would be shortened, amounting to only a minute and a half at 30,000 feet. If the breath is held immediately after the interruption of artificial oxygen breathing, then the time that can be endured without breathing of oxygen amounts to about 1 minute above 25,000 feet. So then when there is a sudden interruption of the oxygen supply above 25,000 feet, the individual should first hold his breath. If the trouble in the apparatus cannot be remedied at once, he should descend rapidly in a steep dive.

e. Calm, slow, and deep breathing with good exhalation is the best kind of altitude breathing. This holds true both for the breathing of atmospheric air while flying at low altitudes as well as for oxygen breathing with a respirator. This is especially important at high altitudes above 25,000 feet.

f. The regulations in effect for the use of oxygen are for altitudes given in feet above sea level. At altitudes above 15,000 feet and without artificial breathing of oxygen there is danger of fatal altitude sickness.

g. General instructions now in existence specify:

(1) Except in urgent, unforeseen emergencies, all personnel will use oxygen at all times while participating in flight above 15,000 feet;

(2) Oxygen will also be used when remaining at an altitude below 15,000 feet but in excess of 12,000 feet for periods of 2 hours or longer; and

(3) When participating in flights below 12,000 feet but at or in excess of 10,000 feet for periods of 6 hours or longer.

h. Regulations may be changed or varied from time to time and all flying personnel must be properly informed.

i. The following is considered advisable at present:

(1) Flights between 25,000 and 35,000 feet should not be permitted except by permission of squadron commanders during training or in

combat, and then only after personnel have received instructions and are thoroughly familiar with the functions, limitations, and use of their equipment. Routine military missions can be performed with the use of oxygen up to 30,000 or 35,000 feet. Greater comfort and efficiency and safety can be obtained at very high altitudes by pressure suits, cabins, or compartments.

(2) Flights between 35,000 and 40,000 feet should not be permitted except as required in combat or in training under proper medical and tactical supervision.

(3) Flights above 40,000 feet should not be authorized except with special equipment for compression and for experimentation.

j. Testing of the oxygen apparatus before a flight is essential to determine that—

(1) Tanks are filled with oxygen.

(2) Connections from tanks to apparatus are tight.

(3) Fat or grease is not used at any joints or valves. Precaution against the use of oil or grease on any oxygen equipment or connections will be especially brought to the attention of maintenance personnel.

k. With the pipestem, take the mouthpiece into one corner of the mouth, breathe out from the other. (Many persons cannot learn to do this and should have an expiration valve.)

l. With an oxygen mask—

(1) Exhaled air goes out through the outlet valve. Connect the mask to the tube from the regulator.

(2) Open the oxygen regulator valve.

(3) Set the valve to the height required.

(4) From time to time read the pressure gage.

(5) From time to time (every 5 minutes) and after movements of the head, test the tightness of the fit of the mask and the outlet valve.

(6) Respiration of pure oxygen is harmless. It is better to begin too soon rather than too late with the use of oxygen.

(7) If the apparatus goes out of order suddenly above 25,000 feet, fill the lungs with oxygen and hold the breath, if possible, until repair or until a descent has been made. The respiration can be held for about 1 minute.

(8) If the apparatus fails slowly, then a descent must be made as quickly as possible, as no oxygen supply in the lungs is available.

(9) In jumping with a parachute from high altitudes the lungs must be filled with oxygen before taking the oxygen masks off and then the breath held as long as possible.

m. After use, the masks and the mouthpiece should be cleaned with warm water containing a disinfectant. Wipe them and dry them with

warm air but not over a heater or in the direct sun as this damages the rubber.

38. Mixture of other gases with oxygen supply.—*a.* Considerable experimentation has been conducted to determine the toxicity of pure oxygen during various hours of exposure at various altitudes. The results of these experiments are sufficiently conclusive to eliminate any hesitancy in using oxygen for flight purposes.

b. Experimentation has also been conducted to determine the results of mixing various percentages of carbon dioxide and helium with the oxygen breathed to decrease the symptoms that develop as altitude is increased. These have been covered briefly in paragraph 25. The experiments are not conclusive but the results that have been attained are not encouraging.

Section VIII

STRATOSPHERE FLYING

39. Pressure cabin airplanes.—*a.* The present trend in modern aviation is toward operations in the higher atmosphere. To make substratosphere flying practical and safe for flying personnel a thorough understanding of the atmospheric conditions imposed upon the human body is necessary. Flights at altitudes greater than 40,000 feet when such operations are to be accomplished by necessity will require sealed pressure equipment, such as pressure cockpits, pressure cabins, or sealed flying suits that can be supercharged to pressures approximating those found between 10,000 and 15,000 feet.

b. To avoid the passengers having to employ an oxygen apparatus in flights over high mountains and bad weather in America, airtight cabins are being provided by commercial airlines in which a positive internal atmospheric pressure is maintained. The oxygen in such a cabin is maintained only at a partial pressure, equal to that of ordinary air at a given altitude.

c. The building of a positive pressure cabin entails no particular technical difficulty, except the added weight and expense, as a positive pressure of three-fourths of an atmosphere suffices to supply the crew with adequate oxygen even when breathing air maintained by compression with the composition of normal atmosphere.

d. (1) Three methods have been studied and are available for administering oxygen to flying personnel at relatively high altitudes. These methods are—

(*a*) Supplying oxygen through individual respiration face masks.

(*b*) Supercharging the cabin atmosphere.

(*c*) Flooding the entire cabin with oxygen. The problem of producing and maintaining a high concentration of oxygen in even moderate size airplanes is very difficult from the standpoint of the amount of oxygen required.

(2) In comparing the practicability of the oxygen cabin with that of the other two methods, the comparison must be based on—

(*a*) Maximum altitude obtainable.

(*b*) Weight and quantity of oxygen required.

(*c*) Certain practical aspects, such as added weight and cost of equipment, comfort, safety, type, and mission of airplane used.

e. In sealed cabin airplanes that are now being constructed it is planned to raise the pressure within the cabin by means of pumps or superchargers until it is high enough to prevent the occurrence of anoxemia. For flights over any long period of time this would seem to be the logical means of preventing oxygen-want and decompression sickness. However, this method is expensive in cost and lowered efficiency of the airplane. There are dangers involved in the use of this type of airplane for military combat aviation in war. If the pumping system failed, or a large leak was produced by a shell or by shrapnel, the pressure would be instantaneously destroyed. In such circumstances, if the airplane was operating at a very high altitude, the pilot and crew almost immediately would become unconscious from the effects of sudden anoxia. To release oxygen into the cabin of the airplane in the event that a large leak occurred would be ineffective, for the reason that as long as a leak was present the pressure could not be maintained. This danger, as well as the expensive construction involved, becomes unnecessary below 35,000 feet if oxygen can be supplied economically and efficiently by means of a simple oxygen inhalation apparatus.

f. The Army Air Corps XC–35 is an experimental pressure cabin substratosphere airplane designed to maintain atmospheric pressures within the cabin equivalent to that of 12,000 feet altitude when the airplane is flying at altitudes up to 30,000 feet. This pressure differential is obtained by means of a pressure tight fuselage into which atmospheric air is introduced by suitable compressors. Ventilation through the cabin is maintained by allowing the cabin air to pass back to the atmosphere through an exhaust valve in an amount exactly

equal to that entering the cabin from the compressors. In this manner any desired cabin pressure differential may be maintained while at the same time a continuous flow of fresh air is available for ventilation of the cabin interior.

g. The pressure cabin equipment of the Boeing stratoliners has operated satisfactorily and created comfortable and pleasant conditions in the cabin during flights of 18,000 and 19,000 feet altitude during regular flying schedules.

h. If in a positive pressure cabin machine which is filled with air at 40,000 feet there is a sudden fall in pressure due to breaking a window or to a shot or shell hole, the pressure may fall in a few seconds.

i. Unconsciousness is to be expected within a minute and a half in the crew of a positive pressure cabin if it is ruptured at 35,000 feet and atmospheric air has been breathed, as the blood loses its oxygen very rapidly. Whether it is possible at 35,000 feet to maintain consciousness for a minute so that the pilot has the chance to put the airplane into a forced dive and attain a lower, bearable altitude is doubtful.

j. The possibility must be considered that the crew of a ruptured positive pressure cabin airplane could be saved if an automatic mechanism were provided to send the airplane into a fast glide to a lower level where the pressure is again raised to correspond to 20,000 feet or lower within a minute and a half. A reduction of altitude of 10,000 feet in approximately 1 minute is not impossible to obtain technically, particularly as the rare atmosphere at this height presents little resistance.

k. The advantage of breathing oxygen in a positive pressure suit is the decreased risk of bodily damage due to a sudden fall of pressure.

40. Positive pressure flying suits.—*a*. A positive pressure suit can only be employed with low positive pressure unless the suit is provided with joints which permit the arms and legs to be moved. In it even with low internal pressure, one experiences a certain rigidity.

b. The pressure must be maintained in a positive pressure suit if only one-third of an atmosphere and the oxygen content of the inhaled air must be increased. Breathing pure oxygen and with a positive pressure to the lungs the highest possible altitude can be attained. The supply of oxygen while in a pressure suit is best supplied by a circulating rebreathing apparatus because this method saves oxygen while absorbing carbon dioxide.

c. The positive pressure suit has the great advantage over the positive pressure cabin for military use in that it can be used in different types of airplanes without change in construction and it is not as

vulnerable to punctures. The positive pressure suit has been used for the latest airplane altitude records in spite of the difficulties in movement that it entails.

d. The suit worn by the Italian, M. Pezzi, in a record flight to 56,000 feet consisted of an impermeable rubber combination and of a metal helmet connected with it. The helmet contained windows which were electrically heated to avoid frosting. In order to prevent the

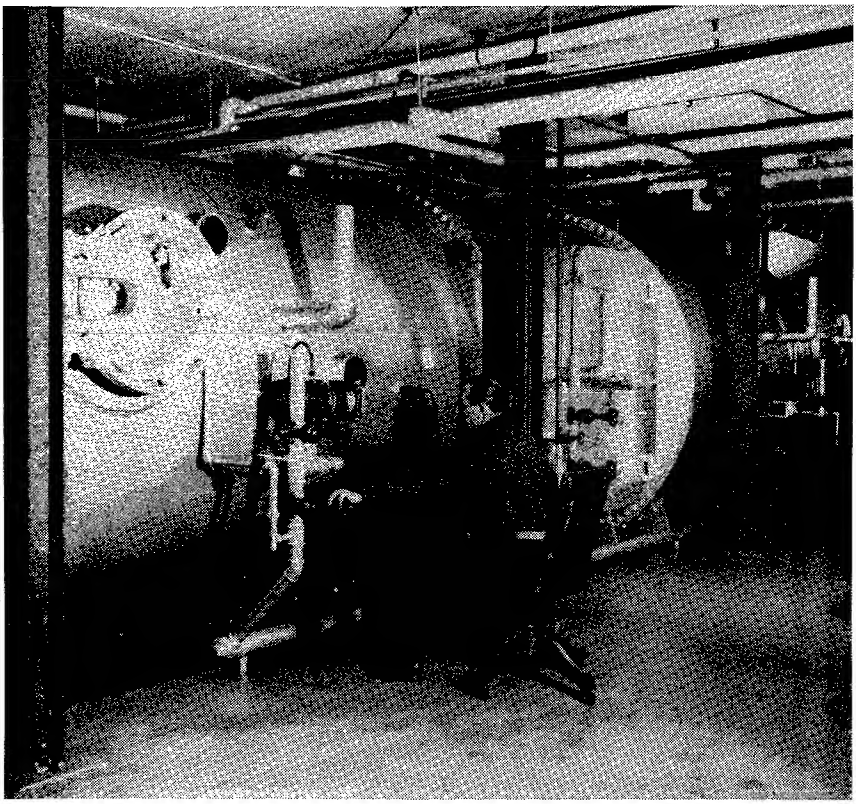


FIGURE 19.—Low pressure altitude experimental chamber.

rubber suit from expanding too much it was covered by a second stiffened cloth combination. The helmet was carried by a metal breastpiece which distributed the weight. The many difficulties that had to be overcome were great. Above all, it was difficult to prevent the internal pressure making the suit too rigid. This was overcome by decreasing the pressure within the suit. The first idea was that a difference of pressure between the inside and outside of one-half of an atmosphere would be sufficient. This would enable the pilot to be

as well off, as far as pressure is concerned, at 50,000 feet as in the open air at 18,000 feet. This pressure can be borne for considerable time when pure oxygen is being breathed. As a protection against the cold, an electrically heated suit was worn inside the rubber one to assure a proper body temperature while the temperature existing in the stratosphere was −60° C. The heights reached were the limits attainable and could only have been attained by well-trained and experienced flyers.

41. Pressure chamber conditioning of personnel for high altitude flights.—*a.* To simulate high altitude flying in the hangar or laboratory is now possible, as technicians have worked out several new ways of testing a pilot's reaction to the thin air of high altitudes without having the airman leave the ground. It is predicted that this will accelerate progress in high altitude training and operations. By a gradual cutting down of the amount of oxygen, a pilot or student aviator sitting safely in the low pressure chamber goes through similar reactions to those that he would experience if he were flying an airplane several thousand feet above the surface. The reduction in the value of oxygen and in pressure is the equivalent of a corresponding ascent in altitude. The purpose of the mechanism is to determine personnel reactions and to find ways to overcome the results of oxygen starvation and prolonged exposure to low pressure.

b. Practical methods have been developed in limiting the effects of aeroembolism by means of decompression (denitrogenation) with oxygen before ascent; this is accomplished by the use of a low pressure chamber. The low pressure chamber of the Aero Medical Research Laboratory at Wright Field, Dayton, Ohio, is shown in figure 19. Simulated ascents to any desired altitude may be obtained in the low pressure chamber apparatus.

c. Flying personnel should be especially selected for high altitude operations and for missions of long duration at high altitudes. Figure 20 shows an individual in a low pressure chamber used for examining aviators and prospective flying students. No matter what the airman's classification may be as to ability to withstand high altitude, he is not allowed to fly above 15,000 feet without an oxygen supply.

d. An aviator should be restricted in his aerial activities to the level at which he is efficient according to pressure chamber tests. Dangerous symptoms may develop at very high altitudes with a dramatic suddenness. Instances of partial or complete paralysis are recorded in chamber tests. Paralysis in such cases may be temporary or permanent injury may result.

e. Altitude training is very important for persons selected for high altitude flying. This training may consist of pressure chamber experience or remaining at various altitudes in the air for specified

FIGURE 20.—Examination of prospective airplane pilot during simulated ascent to high altitude in low pressure chamber.

periods of time. Figure 21 shows several pilots receiving altitude tests and instruction.

f. High altitude training in an airplane is possible only by slow and systematic increase of the altitude on successive flights. It is im-

portant that the training be supervised by a flight surgeon, otherwise altitude resistance may easily be lowered by overtraining. A good form of altitude training is several weeks' stay on a high mountain with sport activity as a mountain climber or ski runner.

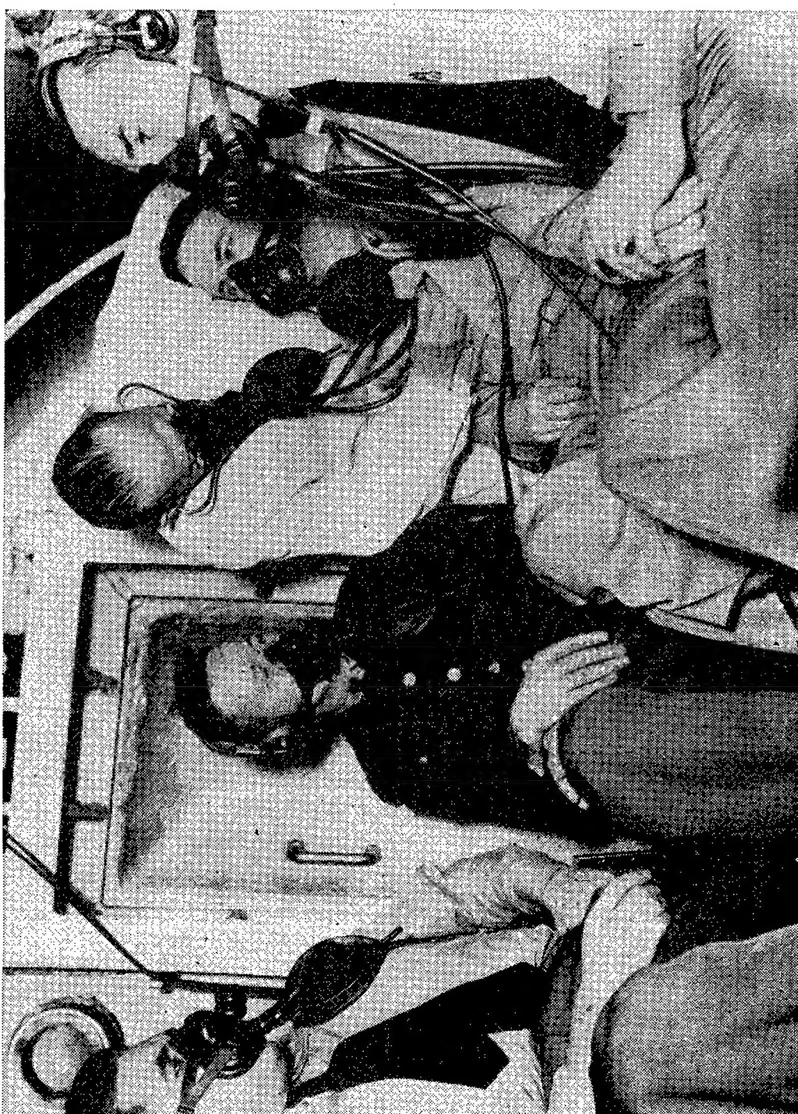


FIGURE 21.—Airplane pilots receiving altitude tests and instruction in low pressure chamber.

g. There has been considerable research to determine the extent to which the decrease of barometric pressure at high altitude will cause nitrogen bubbles to form in the blood. Recent experiments have shown

that large animals, such as goats, are much more satisfactory for the study of high altitude experimentation of decompression sickness than are small animals, such as rabbits. By further research an effort is being made to establish more definitely the effects at various altitudes upon the cerebrospinal fluid pressures during various rates of ascent and descent, also the length of time after collapse before death occurs and to establish more definitely the effect of preoxygenation and decompression in preventing collapse and unconsciousness.

42. Records of highest altitude flights.—*a.* The following are some of the highest altitudes reached:

(1) Colonel Mario Pezzi of Italy, wearing a sealed flying suit, using pure oxygen, ascended to 56,000 feet in October 1938.

(2) Settle and Fordney reached a height of 61,236 feet in November 1933 in a sealed gondola using pure oxygen.

(3) Picard in August 1932 ascended to 53,000 feet in a pneumatically sealed gondola.

The maintenance of a sufficient supply of oxygen and internal pressure at the higher altitudes made these flights possible.

b. On November 11, 1935, Captain Albert W. Stevens and Captain Orvil A. Anderson, both of the U. S. Army Air Corps, ascended to an official world's altitude record of 72,395 feet. As a means of sustaining life and creating environmental conditions favorable for conducting scientific investigations on this flight, a 9-foot airtight "dow-metal" sphere was used to contain the personnel. Installed in this sphere was an air-conditioning apparatus consisting of a standard liquid oxygen storage container filled with 46 percent oxygen and 54 percent nitrogen, a special absorbing unit containing 12 bags of N_aOH through which the gondola air was circulated by a fan, and an aeronoid valve set to maintain an internal gondola pressure of about 9 pounds per square inch. After ascending to about 16,700 feet, the balloon was leveled off, the gondola sealed, and the air-conditioning apparatus placed in operation. While no exact records were kept as to the amount of oxygen vaporized or consumed, no oxygen-want developed in the personnel. The absorbing unit functioned satisfactorily and a graphic record of the relative humidity shows that it varied from 45 percent at the start of the flight to 33 percent at the end. The aeronoid pressure-regulating valve kept the gondola pressure within a range of 8.8 to 10 pounds per square inch. The temperature in the gondola was kept within the range $+6°$ C. to $-12°$ C. The fluctuation in temperature was apparently due to the effect of movement through the atmosphere for the temperature lowered during both ascent and descent and rose while the balloon was leveled off and

at ceiling. From the scientific observations taken on the flight, it was determined that the composition of the rarefied air up to 72,395 feet differs only slightly in composition with the air at sea level. The temperature dropped with ascent from a ground reading of +12° C. to a reading of −60° C. at ceiling. The humidity varied with the temperature and at −60° C. the air contained practically no moisture.

Section IX

PHYSIOLOGICAL FACTORS OF EMERGENCY AND DELAYED-ACTION PARACHUTE DESCENTS

43. Physiological effects of parachute descent.—*a.* Contrary to old theories it has long been established that a free fall in space produces neither unconsciousness nor death. The fear of jumping into space may result in fatal accidents if the airman should choose to stay with his disabled airplane and risk a crash rather than face the unknown and use his parachute. The impulse may be so great that the airman cannot resist the fear of a short free fall. The fear of falling is instinctive in man. It is one that is evident in newborn infants. Most airmen who are forced to take to their parachutes are compelled to overcome or resist fear of a short free fall and to resist the temptation to pull their parachute opening release too soon, which might cause the parachute to become entangled with the airplane and result in fatal consequences.

b. The subject of parachuting becomes of paramount importance in aviation, especially due to the hazards inherent when jumping at extremely high or very low altitudes, also the hazards of jumping from airplanes traveling at extremely high speeds at any altitude.

c. The main purpose of this section is to evaluate the physiological aspects and reactions experienced in and resulting from parachute descents. It appears that the physiological effects of parachute descent vary greatly in different persons. The most important factors appear to be—

(1) Fear and excitement from an irrepressible, self-preservative, instinctive fear of falling.

(2) The nervous and mental process while analyzing the hazards, such as fear of fouling the airplane, possible parachute defects, or hazards of landing, particularly at night.

(3) The effects upon the senses when the parachutist is projected from the airplane into the atmosphere.

(4) The effects of rotation and fall upon the senses before the parachute is opened.

(5) The effects of acceleration and deceleration.

(6) The effects of the shock or force of deceleration at the time of opening of the parachute.

(7) The effects of oxygen-want during descent through rarefied atmosphere.

(8) The hazards during descent of collision or attack by enemy airplanes.

(9) The danger in landing of impact and collision with objects on the earth's surface.

(10) The danger of being dragged by the wind.

(11) The danger of landing in water and becoming entangled in the parachute.

44. Forces acting upon human body during parachute jump.—*a.* The parachute is a device developed to retard the rate of fall by producing a resistance. The resistance produced to descent through the atmosphere is the force necessary to balance the force of gravity and to allow a rate of descent within the limits of human tolerance at the time of impact with the earth's surface.

b. In parachuting there are three forces which have important physiological effects upon the human body:

(1) Acceleration during the free fall (or delayed action) before the parachute is opened.

(2) Deceleration (retardation) when the parachute opens.

(3) Deceleration (impact or retardation) upon making contact with the earth's surface.

c. These three forces must be kept within the limits of human tolerance, which is accomplished as follows:

(1) In the case of emergency jumps where the airplane speed is relatively great, a few seconds of time must elapse to permit deceleration to a velocity at which the parachute can be opened without injury to the body or to the disastrous breaking of the parachute or harness.

(2) The parachutist must delay the opening until the falling velocity of his body has been reduced to within the limits of tolerance to the forces produced at the time of opening. The force imposed by the opening during a normal parachute jump may be as great as 4 or 5 *g*'s but lasts for only a few seconds.

(3) The rate of parachute descent at the time of contact with the earth's surface is determined by the force of gravity and the force of resistance, which are dependent upon the weight, the atmospheric density, and the size of the parachute. The shape (stream lining) of the falling body affects the resistance to fall. To avoid injury when landing from a parachute jump requires particular skill, especially if the wind at the earth's surface is strong or gusty.

d. The standard seat-pack type of parachute and harness is shown in figure 22. There are several other types in use or undergoing experimentation.

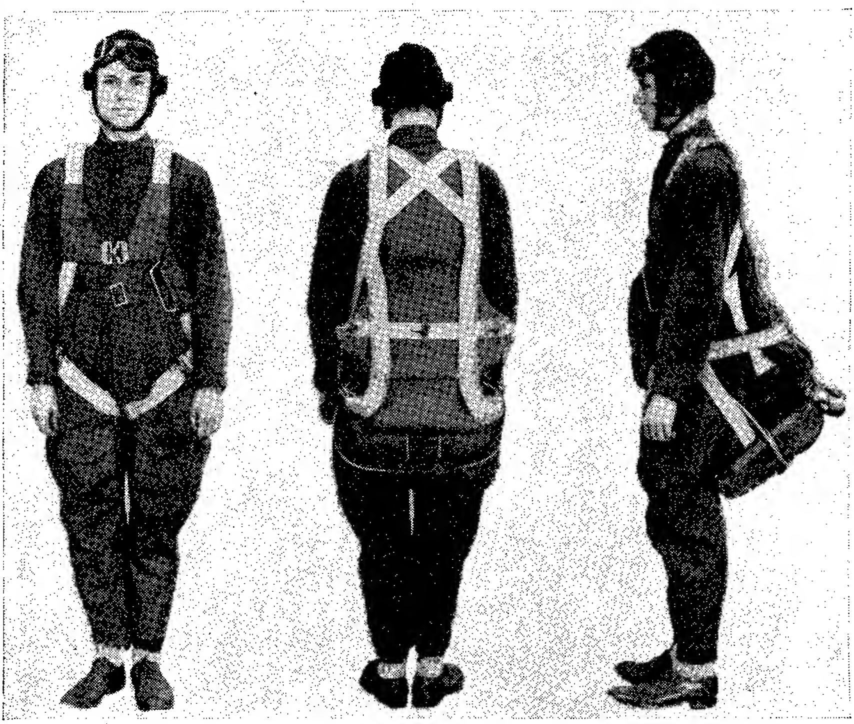


FIGURE 22.—Standard seat-pack type of parachute and harness.

45. Maximum (terminal) velocity of fall.—*a.* A body falling through space without resistance (in a vacuum) will, according to the laws of the force of gravity, acquire a constantly increasing speed. In a space filled with air the falling body encounters a resistance to its motion. In a relatively short period of time a velocity of fall will be reached at which atmospheric resistance balances the force of gravity. This rate of fall is called the "terminal velocity" of fall, after which the body will fall at an almost constant speed, varied only by

the increase in atmospheric density. In the case of a falling man, or a man jumping from an airplane with parachute equipment, considerable resistance is encountered, and the terminal velocity of the fall is quickly reached.

b. If the pilot or crew were required to abandon an airplane traveling at a speed of 250 or 300 miles per hour, great danger would be involved if the parachute should be opened at that moment.

c. While traveling at a great rate of speed, a flyer does not dare expose parts of his body to such terrific pressure. If he held out an arm it would probably be broken, or if his head should project from the cabin it would probably be snapped back with such force that his neck would be broken. Therefore, it is highly important that in making parachute drops from airplanes, speed be reduced before it is possible to jump with safety. For a very short period of time after jumping the parachutist will be traveling at the same velocity and in the same direction as the airplane which he abandons.

d. Experiments have determined that a man equipped with a parachute pack, allowing it to remain closed, will fall at a rate of approximately 120 miles per hour, and that this velocity will be reached in about 1/5 of a minute (12 seconds) during which time a vertical descent of about 1,500 feet will have been made. This presumes a terminal velocity of about 175 feet per second, or approximately 120 miles per hour, at the time of opening. At this terminal velocity of fall the parachute functions smoothly, no undue stresses being realized in either the fabric or harness, and the opening force and shock to the parachutist are not normally sufficient to produce bodily injury.

e. Information as to the maximum landing speed which can be safely tolerated by a parachutist is important. Present day parachutes are designed to land the parachutist at a descent rate of speed of 20 feet (plus or minus 6) per second, depending principally on atmospheric conditions, vertical air currents, and the weight of the parachutist. As a guide to indicate what these speeds of descent mean in terms of some common experience, the following is of interest:

(1) The minimum rate of parachute landings (14 feet per second with a light man in the parachute) would be equivalent to a free jump from a height of 3 feet.

(2) The maximum rate of parachute landings (26 feet per second) would be equivalent to landing after a free jump from a height of 10½ feet.

(3) While jumps from elevations higher than 10 feet are possible under favorable circumstances, the average person would be well shaken up by a 10-foot jump or fall. Add to this the uncertainty of

landing conditions (with respect to terrain, wind velocity, air conditions which may cause the jumper to oscillate, etc.) and it becomes apparent that descent speeds in excess of the present limits cannot be considered safe.

(4) Even the faster rates of descent (20 to 26 feet per second) now permitted would seem to be excessive under the more adverse weather conditions in which parachute jumps are sometimes undertaken, particularly by parachute troops.

(5) The number of sprains and other more serious injuries now incurred in parachute landings offers ample evidence of the severity of the physical strain placed on the body by the present parachute descent speeds.

(6) The net efficiency of the jumping personnel in a parachute troop detachment would probably be decreased at landing speeds in excess of 20 feet per second.

46. Practice of proper technique to avoid injury from parachuting.—*a.* The parachutes adopted at present for *emergency descent* are of the manual type, that is, opened by hand.

b. It is important that those who may have to make emergency parachute jumps obtain training and practice on the ground which will prepare them in the technique of a safe and proper jump, opening, descent, and landing.

c. It has not in the past been considered necessary to train all flying personnel by actual practice in parachute descents, but instruction should be given them in the technique of parachute jumps so that they may know how to jump clear of the airplane in flight or in falling and avoid injury at the time of impact with the earth's surface.

d. In jumping from an airplane one should attempt to jump as far as possible from it in order to avoid striking the tail surfaces.

e. Before reaching the ground, the parachutist should try to obtain the wind direction and maneuver the parachute turning with his back to the wind so that he will not be pulled backward at the time of impact.

f. At the time of landing, the parachutist should hold the legs together and relax the legs and body to absorb the shock of impact.

g. The fingers should be closed to avoid injury. If the wind is very strong and the angle of descent is very acute, the parachutist should then run forward in the direction of the wind, which allows the parachute to collapse more readily. The collapsing of the parachute is accomplished more quickly by the drawing in of the lowest parachute cords, allowing the upper side to spill the air.

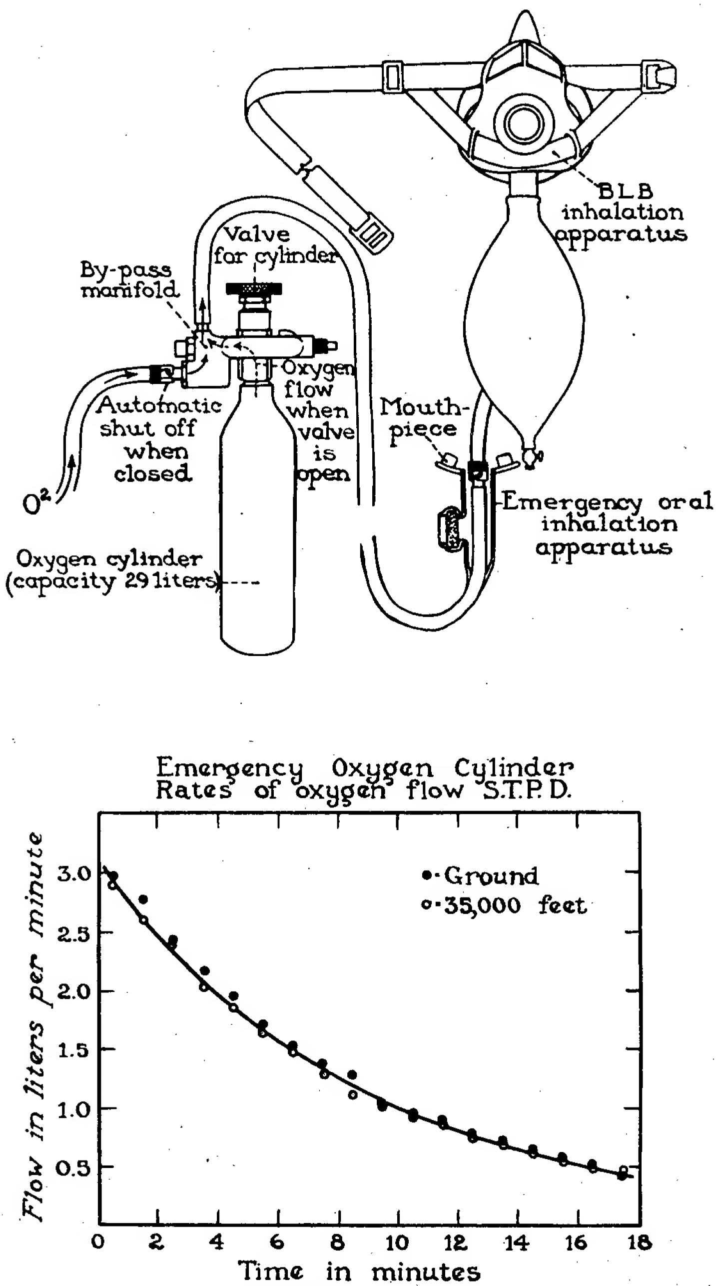


FIGURE 23.—Oxygen apparatus suitable for high altitude parachute descent.

47. Emergency parachute descent from high altitudes.—*a.* Parachute descent from high altitudes during *day or night* combat missions may become necessary in case of damage from enemy fire or from other causes. When parachute descent from high altitude be-

FIGURE 24.—Oxygen equipment installed ready for use by high altitude parachutist.

comes necessary, the two most important considerations are the low atmospheric pressure and the low oxygen pressure of the atmosphere.

b. After the release is pulled and the parachute opens, the parachutist may be suspended in the rarefied atmosphere for 10 minutes,

or even more, during descent before a point is reached where the oxygen in the atmosphere is sufficient to sustain life.

c. While above 25,000 feet oxygen starvation (cerebral anoxia) would take place within $1\frac{1}{2}$ minutes and unconsciousness would develop which would render the parachutist helpless and unable to pull the parachute opening release. Thus death is almost certain to result if an artificial oxygen supply is not provided to avoid unconsciousness.

d. It is necessary to provide an oxygen supply which may be attached to the parachutist to sustain life while descending through the rarefied atmosphere. One type of apparatus developed especially for this purpose is shown in figure 23.

e. Equipment similar to that shown in figures 23 and 24 is being developed for parachuting from high altitudes.

48. Delayed-opening parachute drops.—*a.* All emergency parachute drops require a delayed action for at least a short period of time until the airplane has been completely cleared before the opening release can be pulled safely. Hazardous aerial situations may be avoided by entirely practical means of delayed action of opening in parachute jumps.

b. The factors influencing the duration of the delayed action of opening may be summarized as follows:

(1) Necessity of clearing all parts of the airplane before the parachute is opened.

(2) Danger of a disabled airplane traveling in circles and colliding with the open parachute.

(3) Danger of opening the parachute before decelerating to the terminal velocity of fall when jumping from an airplane traveling at a higher rate of speed.

(4) Danger of oxygen starvation while descending with the parachute open through space from high altitudes of low oxygen pressure.

(5) Danger of colliding with other parachutists during descent.

(6) Danger of attack by enemy airplanes while descending with the parachute opened.

c. When the airplane becomes sufficiently disabled in combat to require the combat crew to take to their parachutes, the crew may become the prey or targets of the enemy airmen while suspended in the air as they float to earth. It appears that the only defense in such a case is a rapid descent downward using the speed and time element of a delayed-opening free fall to escape.

d. When necessary to make a parachute descent from 30,000 feet or higher, the airman would not only abandon his airplane but also his normal oxygen supply. The life of the airman may be saved by

a delayed-action jump and a free fall through the rarefied atmosphere, in case the auxiliary supply of oxygen is not available. If the parachute were opened quickly, unconsciousness or death would occur before the relatively slow descent carried the parachutist to the lower altitudes where the oxygen pressure is sufficient to maintain life. The period of descent from 30,000 to 20,000 feet would require approximately 8 minutes. On the other hand, a free fall from 30,000 to 20,000 feet would require only about 1 minute, during which time unconsciousness *might* be avoided if the breath were held. In most cases where an artificial supply of oxygen is provided during descent, a long delayed opening may not be necessary.

49. Parachute troops.—*a.* In addition to the physiological considerations of emergency parachute drops, which become necessary as the result of the loss of control of an airplane in flight, the consideration of descent by parachute troops is also of importance.

b. Parachute troops are moved by air transport and landed by means of parachutes. Troops landed by parachute are task forces specially organized, equipped, and trained for the execution of particular missions.

c. Due to the split-second precision required in the accomplishment of the mission of parachute troops, it is probable that they may be required to do more muscular work in a short period of time than other military units.

d. Parachute troops should be prepared for their arduous duties by physical exercise and training. They must be kept in a condition of excellent physical fitness, for upon their physical condition will depend not only the success of their mission but their safety during the limited time in which they must get into action.

e. Excellent forms of physical exercise of parachute troops are football, diving, swimming, work in the gymnasium, tumbling, and wrestling. This training enables the parachutist to break his fall, get up immediately, and get into action.

f. Figure 25 shows parachute troops prepared for descent. Each student parachutist wears two parachutes.

g. To reduce the strain placed upon the parachutes and upon the personnel, it is desirable to reduce the speed of the airplane to the minimum consistent with safe flying control. This is extremely important to parachute troops who are released from airplanes usually at low altitudes. If the parachutist jumps from the airplane while it is traveling at 120 miles per hour, he will maintain approximately that same speed until he opens his parachute.

h. The altitude at which parachute troops jump may be varied according to the mission and the conditions under which operating,

but they are usually released at the minimum altitude consistent with safety.

i. The parachutist must be free from hernia, weak heart, or weak bone structure.

FIGURE 25.—Parachute troops prepared for descent.

j. The primary physiological considerations of parachutists are—

(1) Physical condition of the parachutist.

(2) Mental and nervous strain of jumping from the airplane and of going into action quickly.

(3) Mental and nervous strain of the fall in delayed action of opening.

(4) Shock of deceleration at the time of opening of the parachute.

(5) Shock of deceleration at the time of impact or landing at the surface.

(6) Proper depth perception and good judgment in making a successful parachute landing.

(7) Training necessary to maintain the required physical condition.

k. Some of the reactions which should mark a trainee or novice as unqualified for parachute troops or parachute jumping are—

(1) Airsickness, habitual.

(2) Continued hesitancy prior to exit.

(3) Hysteria of any nature.

(4) Loss of physical faculties during fall or descent.

(5) Slow physical reactions to effects experienced.

(6) Lack of physical coordination.

(7) Continued failure to correct errors of technique.

Section X

SPACIAL ORIENTATION; EFFECTS OF RATE OF CHANGE OF MOTION AND OF DIRECTION AT HIGH VELOCITIES UPON HUMAN BODY

50. Spacial orientation.—*a*. By the expression "spacial orientation" is meant the ability of man to determine his relative position or attitude in respect to the earth's surface through the sense of vision and the organs of balance contained within the human ear. Spacial orientation is assisted by the nerve reaction produced by the normal sensation of the force of gravity upon the individual. A man on the ground with his eyes closed determines his relation in respect to the earth by the action of the force of gravity upon the organs of his body.

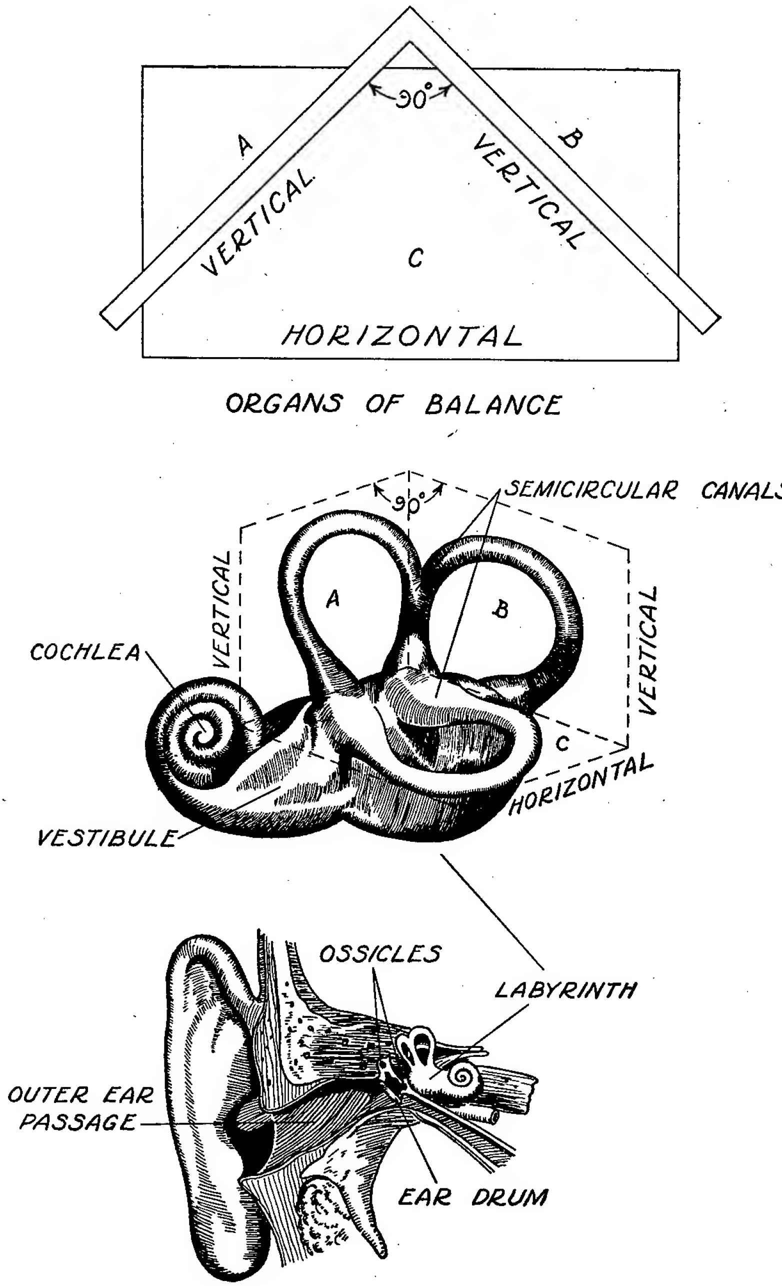


FIGURE 26.—Human ear and organs of balance.

b. The static organism of the ear controls the perception of the direction of the forces of gravity and follows the forces of acceleration and centrifugal force in any plane. It also controls the muscles of the eyes so that when the body turns, objects in space may be seen as if they stood still, and in this way spacial orientation is maintained. The chief function of the organs of equilibrium is to control the movements of the muscles so that they will maintain equilibrium in various positions of the body during its normal movements. The organ of equilibrium in the human ear is shown in figure 26.

c. Spacial orientation and equilibrium are controlled by the combined action of the eyes and the organs of balance within the ear. The eyes are controlled by what they see and by the nerve impulses which are received from the ears. Due to the fact that spacial orientation is controlled by two separate organs united closely with each other by nerve action, it happens at times that the sensations furnished by the ear are contradictory to those of the eyes and other sensory organs. This confuses the senses of spacial orientation and is one of the chief causes of motion sickness while in flight. Many false impressions are registered in the brain, particularly during intrument (blind) flying.

d. So far in their development the ear organs are unable to distinguish between the normal forces of gravity and the sense reactions produced by centrifugal force.

e. As illustrated in figure 26, each of the three semicircular canals which are filled with fluid lies in a plane at right angles to the other two; one of the canals lies in the vertical plane in the forward position; another in the vertical plane at right angles to the first; the third lies in the horizontal plane. In this manner sensations are indicated in all of the three dimensions of motion. As man originally moved primarily in two dimensions on the earth's surface, his sensations to spacial orientation in the third dimension are not as acute as those developed in fish and particularly in birds.

f. Since the senses of sight and balance are connected and operate in conjunction with each other, it is impossible to accomplish complete spacial orientation when vision is shut off, as in instrument (blind) flying. Therefore, in instrument flying it is necessary to provide instruments through which the sense of vision can be brought into action. Such equipment includes orientation and blind flying instruments through which spacial orientation without vision in respect to the earth's surface is made possible.

51. Motion through space.—*a.* Motion through space is expressed in terms of velocity or speed. Speed indicates the distance traveled in a unit of time. In the English system—

$$\text{speed} = \frac{\text{miles}}{\text{hours}} = \text{m. p. h.}$$

b. The question has often been asked, "What speed or velocity can a man in a moving airplane stand?" During the early days of airplane flight, it was predicted that the human body could not withstand the continued effects of high velocities which airplanes might attain. It is now possible to obtain speeds of 500 miles per hour in modern aircraft. This high speed in flight has but little effect upon the human body so long as the speed is constant and the flight path remains in a straight line. However, in susceptible individuals high rates of speed near the ground may produce a sensation of dizziness (vertigo) or cause increased apprehension. Vibration sometimes attendant at high speed causes reflex increase in muscular tension which contributes to production of fatigue and stress.

52. Airsickness due to motion and spacial disorientation.—*a.* Airsickness is a condition which occurs principally as a result of motion and acceleration (both linear and angular) experienced in aircraft flight. It is characterized by such symptoms as nausea, vomiting, instinctive fear, pallor, sweating, dizziness, and prostration. That airsickness is produced by the motions (or accelerations) encountered in flight is indicated by the fact that the frequency of airsickness and its severity, when it occurs, are in direct proportion to the amount and duration of the motions encountered.

b. The rolling and pitching of the airplane alone causes airsickness in susceptible individuals. This is one factor which is responsible for some persons not learning to fly and may be instrumental in causing crashes during training.

c. Airsickness, produced by motion, occurs when conflicting sensory impressions from the organs of equilibrium are present in consciousness, as described in spacial orientation (par. 50). Usually one impression is true and one false. The degree and duration of airsickness caused by motion are in inverse proportion to the ability of the eye to fix an object in the immediate environment and correctly orient the individual in space.

d. The mechanism by which dizziness (vertigo) is produced depends principally upon the motion of the airplane, as the occupant follows the movements and maintains the same relative position in respect to the airplane in flight. This is contrary to normal experience and gives rise to conflicting sensory impressions in consciousness. This

is aggravated in flying by the fact that the earth, the only true point of reference, is usually some distance away and objects on its surface are difficult to fix visually. In turbulent air the occupant of an airplane may suddenly rise 500 feet but, due to the distance of the horizon, his visual sense may receive no such impression.

e. The fact that visual orientation in space tends to prevent airsickness (vertigo) is well demonstrated by the common observation that a pilot who never gets airsick while piloting an airplane himself may become sick when riding as a passenger. The explanation for this is based on the fact that a pilot flying an airplane must keep himself oriented in space at all times to insure proper control. The pilot's feel of the controls gives him some warning of the direction of impending motion and he knows beforehand when he is going to bank or turn. When flying as a passenger, however, this same individual has neither the incentive nor the wherewithal to keep exactly oriented and may find himself disoriented at a time when some point of reference suddenly impresses itself on his consciousness.

f. The relation of the effects on the eyes, ears, and sensations to these disturbances constitutes a physiological problem. Why some airmen overcome them and others do not is still an unanswered question. Some, even after they have become accomplished pilots, are not entirely able to withstand rapid spiral motions or rolls. The location of the individual in the airplane evidently has a bearing on the causes producing nausea and dizziness in spirals and turns, as these symptoms are aggravated if the individual is in the rear of the airplane.

53. Forces and effects of acceleration.—*a.* Acceleration is the rate of increase of velocity.

b. An airplane in level flight and traveling at a constant speed is influenced primarily by gravity, the lifting and propelling force. Independent forces are produced by the airplane.

c. Maneuvers which are possible in the present high speed airplanes produce forces great enough to cause permanent injury to personnel. It is, therefore, important to determine the maneuvers and resulting forces which may incapacitate the average individual and those which may produce permanent injury. The relative frequency in the past of aircraft accidents resulting from the effects upon the pilot of acrobatics or maximum maneuvers may be partially explained as the result of these factors.

d. Every body continues in its state of rest or uniform motion in a straight line unless impelled by external force to change that state.

e. The force that is required to produce a given acceleration to an object is dependent directly on its masss. This is expressed by formula as follows:

$$\text{force} = \text{mass} \times \text{acceleration}$$

$$\text{acceleration} = \frac{\text{force}}{\text{mass}}$$

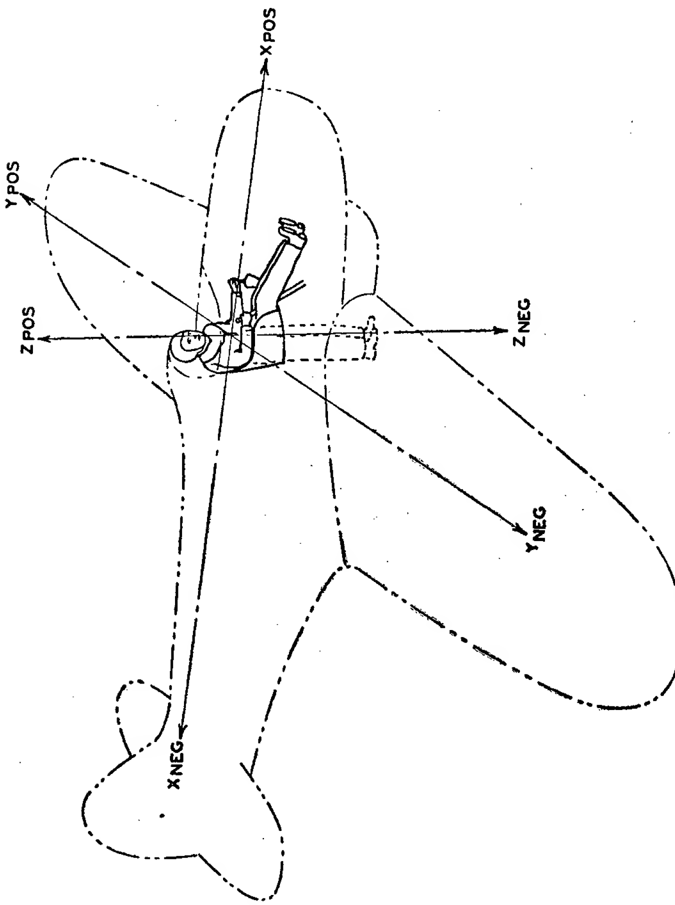


FIGURE 27.—Three axes of rotation of airplane in flight.

f. According to the law of gravity, the earth exerts an attraction on all bodies in a direction toward its center. If any object can fall through space without resistance, as in a vacuum, there will be an increase in velocity or in acceleration which is referred to as the acceleration due to gravity. Under the conditions stated its value is about 32.2 feet per second. If a body is resting in a state of equilibrium without motion and cannot be moved by the force of gravity, it will

exert a force upon its supported base which is equal to the force of gravity and represents the weight of the body. Therefore, the weight of a body at rest is always the force of gravity and is represented by the symbol *g* or 1 *g*.

g. A simple balance or weighing device may be used to measure the force of gravity (weight) of a body at rest. A device, known as an accelerometer, has been developed for measuring the reaction forces of a body resulting from accelerations (positive or negative) which are being imposed upon it. This instrument is normally calibrated to read in multiples of weight or *g*.

h. To establish conventions to indicate forces acting along the airplane's axis of flight or along its vertical or lateral axes, a diagrammatic sketch is shown in figure 27 which represents an airplane cockpit in which a human figure is seated erect in the conventional manner. The heart is used as a center through which three axes, indicated by the symbols *X* for the forward and rear, *Y* for the lateral, and *Z* for the vertical, correspond in general with the three axes of the airplane maneuvers. The directions of the forces acting along the axes, shown in figure 27, are necessary to designate a positive and negative direction for each of the axes.

i. *A force directed in one direction by the airplane produces an equal but opposite force in each of the flying personnel*, so that the effect of the forces acting on the man seated (fig. 27) is in the direction opposite to the force acting on the airplane, that is, when the airplane acts on the body with the force in the direction *seat to head*, the inertia of the human body acts in the direction *head to seat*. However, in studying the physiological effects upon the human body, forces will always be considered as applied in the direction in which the body reacts. It is usual in engineering terminology to indicate the direction of forces which are acting upon the airplane. But in physiological studies herein it is necessary to consider the direction in which the body reacts to these forces.

j. Through experimentation and test, as well as by personal interview with many airmen, both military and civilian, much data and information have been collected which are of very great value in determining the safe limits of forces produced by aircraft maneuvers.

k. In the subject of acceleration, it does not appear that straight and level flying presents any very great problem, but the question of angular deviation and changes of direction at high speed becomes very important, as it is possible to load or weight the body to the extent that injury or death is possible.

l. The forces of gravity affect the average airman as follows:

(1) The force of gravity (*g*) is that normally experienced by the body in the upright position and is the same experienced in walking or moving the body from place to place.

(2) When a positive force of 2 *g*'s is acting upon the body vertically or from head to seat in the sitting position, there is a sensation of awareness of the increased pressure of the body on the seat and the heaviness of the hands and feet.

(3) When a force of 3 *g*'s is acting upon the body a sensation of heaviness of the body and limbs becomes more severe and movement is accomplished with greater effort.

(4) When a force of 4 *g*'s is acting upon the body, the head and body, unless well supported, will not remain in position without great difficulty.

(5) When a force of 5 *g*'s is acting upon the body, the body is beyond the control of the movements except for slight movements of the head, arms, and feet, and under this condition one is physically helpless. When a force of 5 *g*'s is acting upon the body, the weight is multiplied five times.

(6) When a force of 6 to 7 *g*'s is acting upon the body, a visual veiling, greying, or blackout will be experienced in most flying personnel.

(7) When a force of 8 *g*'s or above is acting upon the body, semi-consciousness or unconsciousness may result.

54. Transverse accelerations and forces.—*a.* Forces of acceleration, acting in all other axes of the body perpendicular to the long axis, should be expected to produce effects which are sufficiently similar to permit studying and analyzing them together as a group. As they are usually of relatively low magnitude they are, therefore, designated together herein as "transverse forces" when referring only to the human body.

b. In catapult take-offs and arrested landings, the accelerations do not usually exceed 4 *g*'s, and these do not produce serious results upon the body provided it is properly supported. The normal flying position of the body during transverse accelerations of moderate value is such that tolerance is better than during either positive or negative accelerations through the long axis of the body. It is probable that in the relatively near future higher accelerations acting transversely through the body may also be of great importance. These transverse accelerations occur in catapult take-offs and in arrested landings which are already a reality in operations from naval vessels. Catapult take-offs may become important in surface land take-offs to reduce the

length of runways or to increase the maximum load of the airplane. Greater airplane speeds or even rocket flights may eventually become practical, in which case the high accelerations may make it necessary that the crew and occupants be placed in prone positions during the period of acceleration. Even in the present high speed airplanes, gunners, bombardiers, photographers, etc., may be better protected during combat if placed in prone positions, which would change the direction of force produced by high centrifugal forces from the vertical to the transverse axis of the body.

c. Pilots flying airplanes which contain personnel in standing position, such as parachute troops, air infantry, etc., must take great care that during all turns centrifugal forces do not exceed 4 *g*'s. In violent maneuvers the accelerations may become so great as to throw the members of combat crews out of their normal positions and render them entirely helpless and perhaps produce injury, unless they are securely strapped in position or placed in a prone position.

55. Effects of centrifugal forces.—*a.* Modern military airplanes are now capable of operating at speeds between 300 and 500 miles per hour in combat. The rapid accelerations and decelerations to and from such velocities and particularly changes in direction produce forces which act upon the airplane and flying personnel to the extent that dangerous conditions are encountered which must be taken into consideration.

b. It is possible that a speed can be attained which, when a turn is made, would produce forces sufficiently great on the various liquids and parts of the body, including the brain, in such a manner as to cause death.

c. Combat tactics may be modified in the future by the influence of high stresses produced by maneuvers at high speeds. There is no other physiological effect which occurs in flight that appears with greater suddenness or that causes more serious physical effects than those which are caused by high values of centrifugal force produced by rapid changes in direction. There are combat, flight test, and training maneuvers of military aircraft which require that pilots and other members of combat crews be subject to high accelerations and centrifugal forces. Therefore, this problem must be understood by flying personnel.

d. The following maneuvers in flight have been studied for the purpose of determining the duration and forces produced at high speed:

(1) Loops.
(2) Push-downs.
(3) Pull-outs from dives.
(4) Pull-ups from horizontal flights.

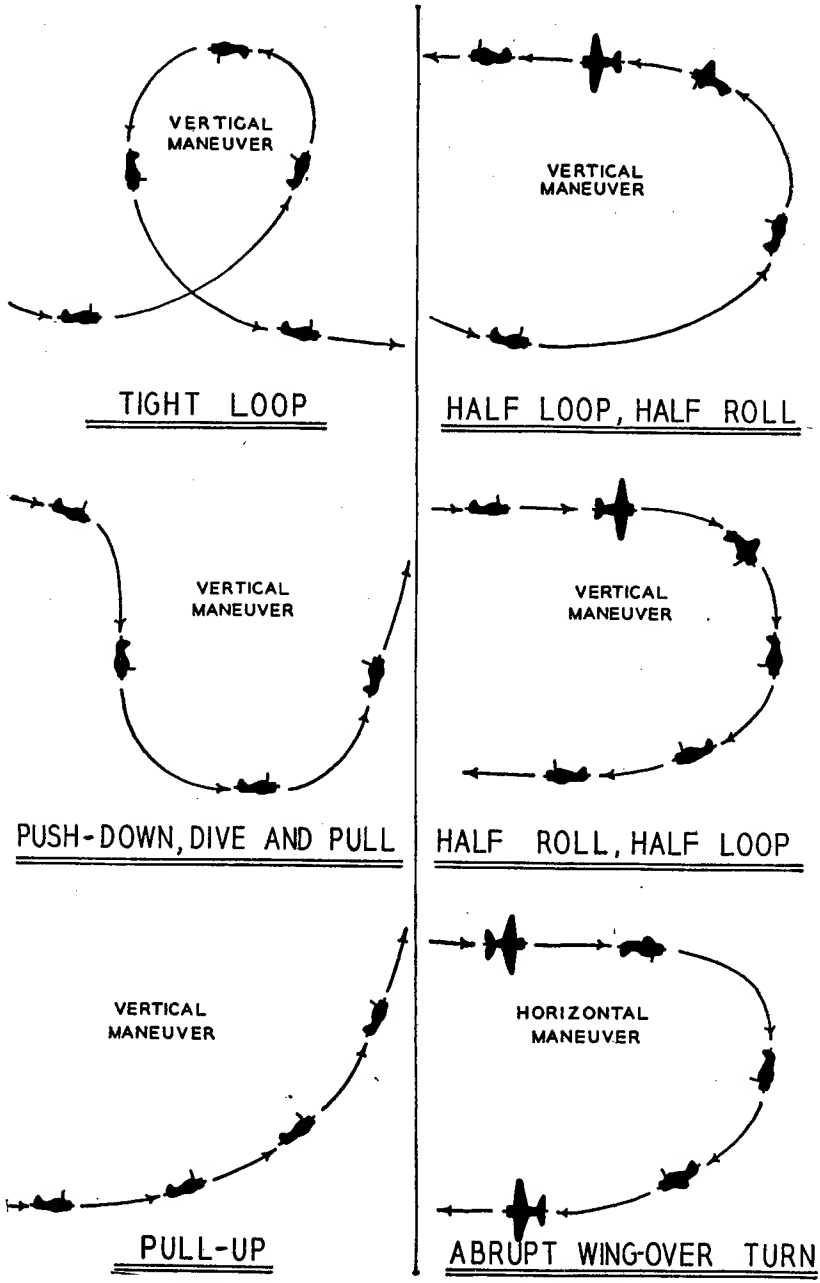


FIGURE 28.—Diagram of six airplane maneuvers.

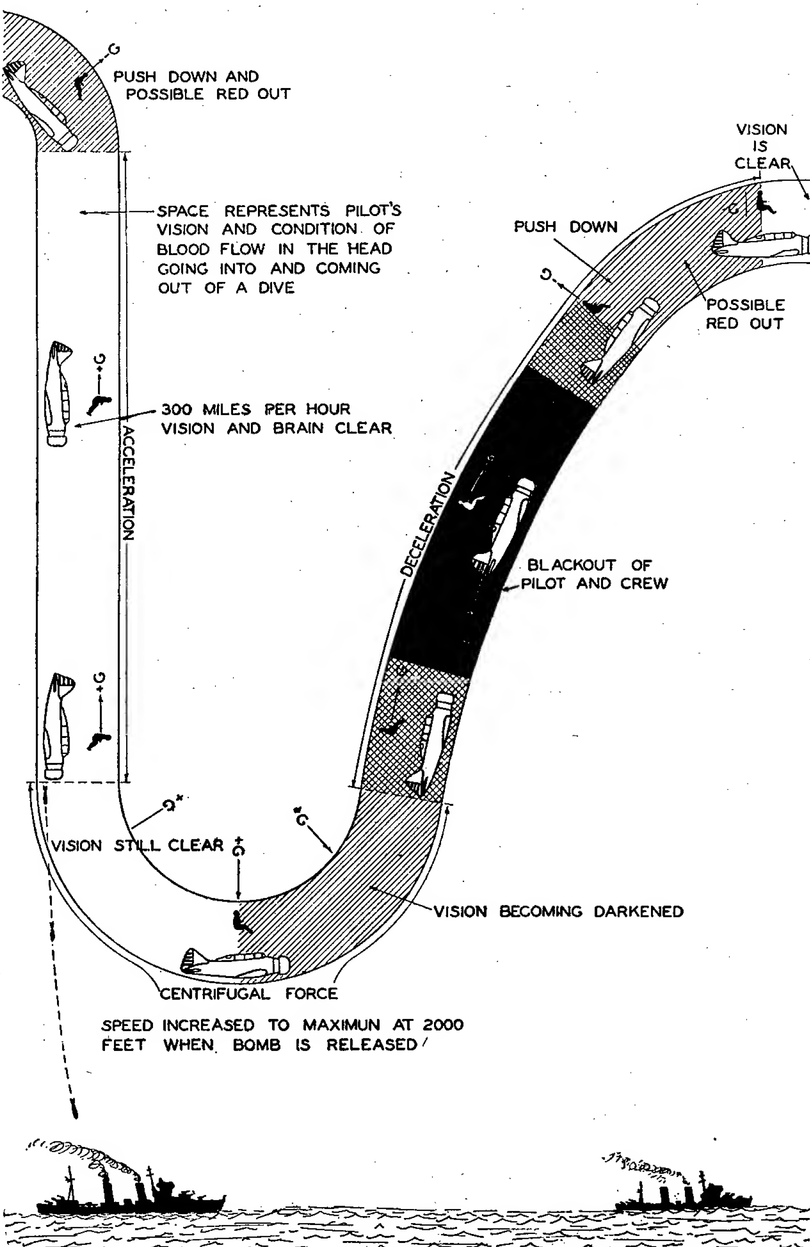


FIGURE 29.—Effects of acceleration, deceleration, centrifugal force, and push-down.

(5) Turns of 180° in vertical and horizontal planes.

(6) Aileron maneuvers.

(7) Rudder maneuvers.

(8) Turns for the determination of minimum radius of turn.

(9) Power-on and power-off spins.

(10) Rolls.

e. In a maneuver where the airplane changes its direction to make a rapid turn or climb, the crew are pressed into their seats by the centrifugal force. Centrifugal force is inversely proportional to the radius of turn and proportional to the square of the speed.

f. The stresses produced by centrifugal force and acceleration may lead to the loss of vision and unconsciousness, and under extreme conditions may become long lasting. Therefore, there is a limit in maneuvers beyond which the human system and the airplane cannot endure, and it is important that this be determined and not exceeded.

g. During a flight in the air, a failure of the pilot for a second might result in disaster. The most intense concentration of vision and of all fighting energy is necessary. The pilot in combat may be lost if he loses sight of the enemy for an instant. Figure 28 is a diagram showing the positions of the airplane and pilot during six of the most common airplane maneuvers.

h. The greatest centrifugal forces will be experienced by fighter aircraft in combat or in dive bomber aircraft at the time of pull-up. In dive bombing attack, bombs may be released from the airplane in a steep dive, at high speed, and at relatively low altitude, as illustrated in figure 29. To avoid striking the ground the airplane must be rapidly pulled out of the dive. In such a maneuver the airplane will be subjected to great forces which will be transferred to the combat crew. The linear acceleration in such a dive is not so important as are the centrifugal forces when the pull-up from the dive begins, at which time the forces during recovery may be as high as 8 *g*'s or greater, as at the bottom of the turn in figure 29.

i. In considering the effects of accelerations and centrifugal forces on the human body, those elements of the body which are capable of motion, with respect to the bony framework, may be grouped into two classifications:

(1) Organs suspended within the various body cavities.

(2) Body fluids which are free to move when acted upon by pressure or centrifugal forces.

j. The physiological effects resulting from accelerations are caused by the inertia of the body components during rapid changes in speed, direction, or both. The most common of these effects arises from the tendency of the blood mass to move in the direction of the centrifugal

force. The greatest effects, as would be expected, are produced in the longitudinal axis of the body. In this axis the blood is either forced toward the head or toward the feet.

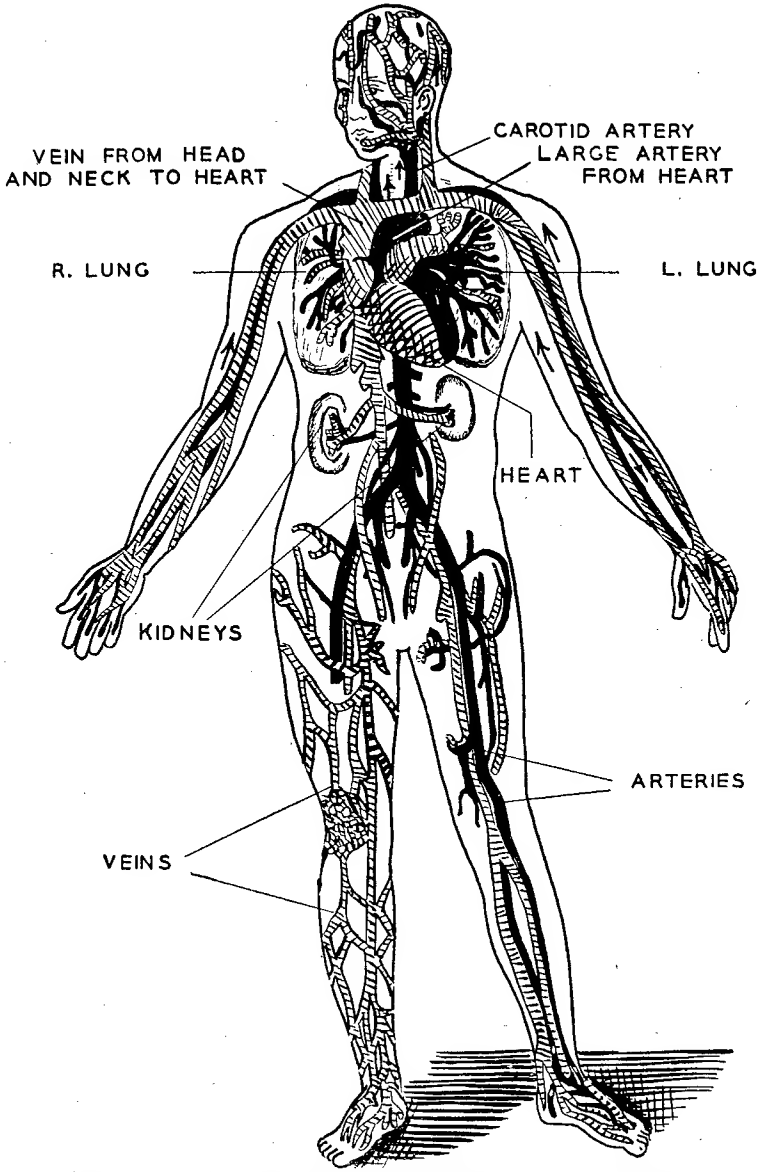


FIGURE 30.—Blood distribution of body showing veins and arteries.

k. The great danger in tremendous speed is in pulling out of a dive sharply or in violent maneuvers. The effects produced vary

with the magnitude of the force and the duration of its action. If the flyer makes an abrupt change from his original line of flight, the centrifugal force acts in the direction from center of turn of the airplane in flight, that is, away from his head and toward his feet. The result is that the blood is literally thrown away from the brain, causing cerebral anemia or a faint.

l. The force upon the body is usually transmitted approximately parallel to or through the long axis of the human body when seated in the conventional manner for flying. Therefore, the effect of forces directed through the body from seat to head and from head to seat is of first importance.

m. Figure 30 illustrates the blood distribution in the arteries and veins of the body. The shifting of the blood mass produces dangerous conditions.

n. This shifting of the blood away from the head produces a blood deficiency (cerebral anemia) such that in the average, normal, young adult, forces equal to about five times the pull of gravity cause temporary loss of vision, and forces exceeding eight times the pull of gravity may cause loss of consciousness.

o. There are two types of reactions to forces which produce loss of vision, and the symptoms depend on the direction of the forces with respect to the longitudinal axis of the body.

(1) When the force, acting on the body in the head to seat direction, reaches a value of about $+6$ *g*'s or greater, a phenomenon known as "blackout" occurs. The symptoms are a gradual darkening of the entire visual field until vision is completely lost. If the force is sufficiently increased there are other disturbances of sensory functions and unconsciousness occurs.

(2) During a negative force which is applied in an opposite direction, seat to head, approximately -3 *g*'s, the visual field assumes a reddish hue which is commonly known as "redding out."

p. The diagram shown in figure 29 is intended to represent the loss or blackout of vision as it occurs in making a sudden change in direction at high speed. In this diagram the airplane swings upward rapidly, producing centrifugal force during the change of direction. The force produced on the airplane and on the human body may be many times the force of gravity during the change of direction. This makes the pilot's body many times heavier than the normal weight and forces the blood from the brain and upper body into the lower parts of the body. After 3 to 5 *g*'s are reached and maintained, there is a feeling as though the blood were draining away from the head and face. The visual mechanism, being peculiarly sensitive to lack of oxygen or blood-flow, fails to function and when 6 *g*'s are reached

or exceeded, a dark curtain usually flashes over the sense of vision causing the blackout, the effect being in proportion to the force and time endured.

q. The effect of high positive forces appears to be worse immediately after rather than during the acceleration. The time-lag between positive centrifugal forces and shifting of the blood mass is such that about 3 seconds are required from the time the force is produced until the full physiological effect is realized. As a consequence, the shorter the duration of any centrifugal force (under 3 seconds) the less the physiological effect.

r. As high centrifugal forces are experienced, and the subjective symptoms increase in intensity, the feeling of pressure or increased weight against the feet and the heaviness of the hands and feet are increased so that at forces from 5 *g*'s up the body becomes practically immobilized in position. At higher forces even short periods of time are sufficient to produce a loss of vision, and semiconsciousness or even total unconsciousness may be experienced.

s. Under such force there is a distinct sensation of a heavy pull on the internal attachments of the body, the blood is felt to leave the head and face, and a complete loss of vision is probable. Respiration becomes more difficult due to the lowering of the diaphragm and the pull of the internal organs. In extremely violent flying maneuvers, permanent damage may result to the central nerve system and internal organs and actual fractures are possible. Forces of maximum value may produce anemia, trauma of the brain, and a congestion of the organs of the body below the level of the heart. The tearing away of organs from their attachments or rupture of the brain has been expressed as possibilities under extreme conditions.

56. Effects of forces acting from seat to head.—*a*. A negative force, (that is, acting from seat to head) of -3 *g*'s is a very disagreeable experience. Negative forces cause a shifting of the blood away from the lower portion of the body to the head region and produce congestion in the head and face accompanied by a sensation as though the skull were expanding and the eyes protruding, and may be followed by a headache lasting for several hours. This effect on the head offers an explanation for the redding out when forces are acting in that direction.

b. This shifting of the blood to the head region results in a high blood pressure in the head so that above -3 *g*'s symptoms of concussion and above—5 *g*'s massive cerebral hemorrhage may occur and death result. There is little time-lag in the effect of these negative forces, there is no tolerance developed, and there is no known method of counteracting the effects.

c. Negative forces which are of considerable value in aircraft are not often encountered. However, outside spins, inverted spins, outside loops, push-overs, inverted flight, and flight testing for negative safety factors all involve negative forces and in these cases become very important.

d. For a negative force equivalent to $-1\ g$, the sensation is the same as that of hanging head downward with a feeling of the upward displacement of the organs of the body.

e. Negative forces produce a marked rise in response of the pulse. At about $-4\ g$'s, pulse rates were observed of about 135 to 150, which are equivalent to those resulting from positive forces of $+7$ or $+8$ g's as shown in paragraph 57. The mental condition produced by negative (seat to head) forces seems to be much more serious than from positive forces. The after effects of head to seat forces may pass away completely in a few minutes, while the effects of seat to head forces may persist for several hours.

f. The danger of prolonged mental confusion, unconsciousness, or cerebral hemorrhage, with subsequent permanent injury or death from relatively low negative forces of -4 to -5 g's, mut be brought to the attention of all flying personnel. The execution of maneuvers involving negative forces in excess of $-2\frac{1}{2}\ g$'s should not be permitted.

57. Effects upon blood pressure and pulse rate produced by acceleration and centrifugal forces.—*a.* As the forces acting upon the body increase, the respiration and the volume of breathing also increase proportionately. Armstrong has shown that the blood pressure decrease and the pulse rate increase are approximately proportional to the time of exposure to the multiplied forces imposed.

b. The average maximum increase in pulse rate and the decrease of blood pressures in relation to the forces of gravity are shown diagrammatically in figure 31. The forces and resulting pressure values produce the shifting of the blood from the head region with its consequent anemia of the brain and optic apparatus, which accounts for the blackout and the coma that accompanies it. The inertia of the blood and the consequent lag explain why high accelerations of short duration are better tolerated than lower accelerations of a longer duration of time.

c. Only two of the fluids within the body are considered: the blood, due to its mass and important functions; and the cerebrospinal fluid, due to its intimate association with nerve centers.

d. As acceleration and centrifugal forces increase, the blood becomes heavier, and therefore the pressure differences within the circulatory system are changed by the increase in the blood weight. When these forces reach a value of 6 g's where blackout usually occurs (when

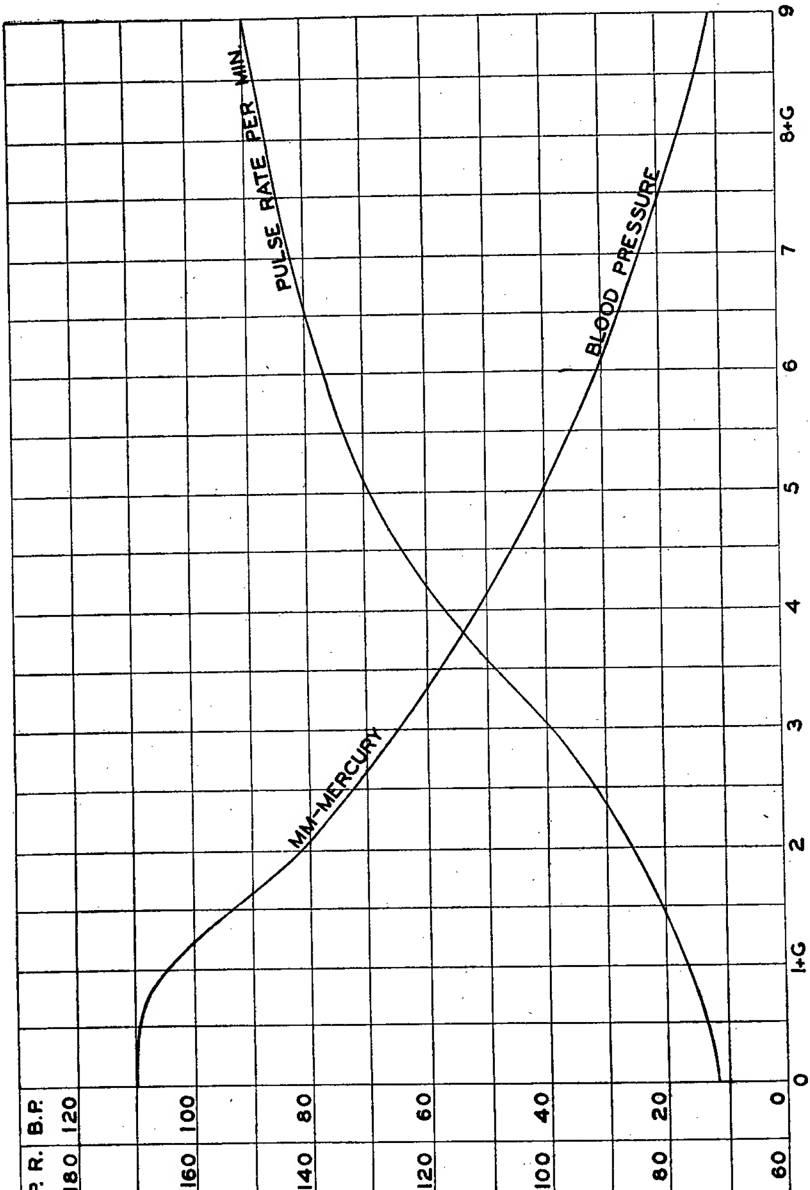


FIGURE 31.—Effects of acceleration $(+g)$ and centrifugal forces upon blood pressure and pulse rate.

seated in the normal position), the blood becomes six times as heavy as normal.

e. As the forces of acceleration or centrifugal force are decreased, consciousness returns quickly, followed by return of vision and a few moments of mental confusion.

f. During accelerations from 2 to 5 *g*'s, the respiration increases and the inhalation-exhalation ratio is increased.

g. If the centrifugal force is not too great, the circulation adapts itself upon recovery and respiration returns to normal.

58. Tolerance to acceleration and centrifugal forces.—*a.* There are variations in individual tolerance to high accelerations, and the determination of individual tolerance is important in the selecton of flying personnel for high performance aircraft. It has been found that individual tolerance to high values of forces, according to the value at which blindness or unconsciousness appears, varies considerably from day to day and depends very much upon the presence of fatigue or on general physical condition. Repeated accelerations during a flight usually decrease tolerance. Selection of personnel may become necessary to accomplish the maximum performance of high speed airplanes in combat. The effects of training, age, and physical fitness must be studied to increase safety and efficiency.

b. It is obviously useless to develop aircraft which can perform beyond the ability of human endurance. It is probable that there are methods of increasing the tolerance of the average human to high accelerations either by changes in the structure of the airplane, the seating arrangement, by the development of special equipment, and by training.

c. Airplanes under test or in tactical employment, which require the occupants to tolerate positive accelerations greater than five times the force of gravity, should be flown only by pilots who have demonstrated their ability to tolerate such accelerations and retain full command of their faculties.

d. In aircraft which may be designed for tactical employment involving accelerations in excess of eight times the force of gravity, provision should be considered for placing the occupants in the prone position with the long axis of their bodies in the same plane as the long axis of the airplane.

e. Consciousness is usually maintained during forces between 6 and 8 *g*'s, depending upon the tolerance of the individual and the duration of time. However, as duration of time is increased, a loss of vision and partial consciousness or total unconsciousness may be experienced from accelerations between 6 and 9 *g*'s. The duration of

any given force of acceleration or centrifugal force is a vital factor, the effect being in direct proportion to the time endured. A decrease of tolerance will be realized from repeated accelerations during a flight, but an increased tolerance following a period of daily exposures. The principal factors which influence the tolerance of these forces are tabulated as follows:

(1) Value of the force.
(2) Time duration.
(3) Physical condition of the individual.
(4) Mental state of the individual.
(5) Physical tolerance of the individual.

f. The tolerance or endurance of flyers may be raised by training of the abdominal muscles.

g. The assumption of the crouching position is a method of keeping the brain in a position in which the blood is not easily forced downward. According to theory and experimentation, the limit of tolerance for average pilots against blackout, when sitting in the conventional upright position, appears to be about 5 *g*'s for 4 seconds of time, or when bending over (crouched), between 6 and 8 *g*'s for 4 seconds. For resisting centrifugal forces the most favorable position is lying down. Experience and experimentation would indicate that no person is able to withstand a centrifugal force greater than 8 *g*'s when sitting in the upright position. Visual disturbances will occur at about +6 *g*'s, and consciousness will usually be lost at a value above 8 *g*'s. However, these values are for well-trained, physically fit personnel. Those less fit will be affected by much lower forces of shorter duration. It appears that by bending forward in a crouched position the tolerance to centrifugal force can be increased by about 2 *g*'s.

h. Methods which will prevent the blackout are of extreme value in the fast-diving tactics of our fast fighters and interceptors, since the strength of our airplanes now permits diving and pull-outs at extremely high speed. Where high accelerations are to be endured, safety devices in the form of broad safety belts and high rudder bars to raise the feet are essential. The purpose of the belt is to secure the pilot firmly to his seat, so that he has the proper feeling of being completely a part of the airplane which he is operating, to prevent the upper part of his body being violently thrown forward, and also to prevent the accumulation of blood in lower parts of the body, thereby keeping a more nearly normal rate of supply to the brain and upper organs of the body. During violent maneuvers, safety equipment is important for other members of the crew as well as for the pilot.

59. Additional factors affecting tolerance.—*a.* When great centrifugal forces are to be resisted, it is very important not to go into the air with an empty stomach. Likewise, it is very important not to fly after a very heavy meal. It is particularly important not to fly on an empty stomach if the personnel have had a sleepless night, as relatively smaller centrifugal forces will produce disability. The use of the correct items and amount of food is important before ascending in flight, especially for a long mission, as digestive disturbances which may be caused in flight are very distressing and add to the other factors tending to reduce physical efficiency. Therefore, a menu must be prescribed so that the correct food is consumed in sufficient quantity to prevent hunger and to furnish the body with proper nourishment.

b. The combination of loss of sleep with alcohol, excessive smoking, and fatigue will have a lessening effect upon the physical tolerance. The tolerance to centrifugal forces and to altitude sickness is very much reduced by diseases, which include fever, digestive disturbances, and fatigue.

c. When the effects of altitude and motion sickness are combined with deceleration and centrifugal forces, they combine to reduce resistance and to produce fatigue and stress.

d. Continued research and study in the development of equipment to assist airmen in overcoming the effects of acceleration and centrifugal forces and many other hazards encountered in the air will contribute greatly to safety and efficiency in the performance of all military missions.

SECTION XI

PSYCHOLOGY AND ITS APPLICATION IN AVIATION

60. Psychology in aviation.—*a.* The application of psychology in aviation has become more important as the development of flying has progressed. In the studies of industrial psychology an attempt is made to find in an individual the trait or combination of traits which will tend toward success in any given field of endeavor. Intensive studies have been carried out for many years in the search for those psychological attributes which are necessary in a military pilot. As a result of these studies a number of psychological mani-

festations have been outstanding as characterizing the successful trainee and experienced pilot.

b. Individuals who apply for military flying training are all given, in addition to the extensive physical examination, a critical psychological survey which results in a "flying adaptability rating." Those who are accepted are considered to be psychologically as well as physically fit to undertake flying training and to perform the duties that will be demanded of them upon completion of their training. Obviously, it would be valueless to select and train pilots and airmen properly if they are not then kept up to an active and efficient level of mental and physical fitness.

61. Psychologic characteristics.—*a*. Some of the important psychologic features which the trained pilot possesses and which should be maintained are as follows:

(1) *Average or better than average intelligence.*—This implies the capacity to deal quickly and effectively with new situations and to understand and solve new problems by applying the results of past experience.

(2) *Good perception.*—This is the ability to perceive quickly and accurately through the various senses (visual, auditory, etc.). This depends not only upon the perfection of the sense organs, but upon quick and accurate integration by which useful and perceptual reactions are achieved.

(3) *Good memory and associative thinking.*—The latter depends upon retentiveness and expresses itself in the various forms of judgments and decisions. The memory traces must be sufficiently labile and near enough to consciousness so that the cognition of associative thinking is rapid and accurate and so little influenced by abnormally accented emotions that the results are correctly evaluated with the present experience.

(4) *Normal rapidity of learning and habit formation.*—This includes a stable and plastic learning faculty for the quick formation of association pathways, giving correct and successful reactions. The correct habits are quickly acquired and incorrect ones easily and quickly discarded.

(5) *Normal span and control of attention.*—The desirable type shows this faculty developed to just the proper degree, avoiding a too highly developed degree of concentration with a proneness toward absent-mindedness and also avoiding the opposite extreme of distractability with a complete lack of capacity to concentrate at all.

(6) *Normal emotional response.*—Emotions are directly connected with the driving power of the organism and are most important in all mental processes.

(7) *Nervous stability.*—This implies the capacity to maintain consciousness, keep one's presence of mind, and avoid faints and automatic behavior.

(8) *Good reaction time.*

b. Many of the above psychological traits, such as intelligence, memory, learning ability, and nervous stability, still remain at a satisfactory level with little attention paid to them so long as the trained flyer maintains normal health and lives a properly balanced life.

c. At times any or all of these necessary psychological attributes may be so profoundly affected by diseases that the individual becomes unfit psychologically for further flying duties. Illnesses, involving the nervous system and brain, especially, will be of such a violent nature that they will come quickly to the attention of the flight surgeon, and the appropriate action will be taken toward relieving the individual from flying and the institution of treatment. A more incipient ailment, flight stress, or staleness will be considered in section XIII.

62. Conscious and subconscious mind.—*a.* The discussion of the subject of consciousness and subconsciousness is too extensive to cover in this manual, but the more one knows about the human mind and its functioning the more one realizes its intricacies.

b. In the pilot the normal fears are often pushed down into this subconsciousness where they are seldom seen by any except by the symptom reactions of the pilot's mind. He is often afraid to let anyone into his confidence for different reasons. It has been said that the better the pilot the better his ability to subjugate his normal inhibitions and anxieties.

c. But, given the proper stimuli, those suppressed inhibitions and anxieties will become evident. The nearer they are to the surface, the more energy used in forcing them down and the more waste put back into the system and more strain developed. It becomes a vicious cycle from which many of the things when grouped together are labeled "fatigue."

d. An important consideration in flying which may be conditioned and influenced by one's varying experiences from day to day is the factor of emotion. Disappointments, financial worries, family or official troubles may suddenly upset an individual who previously had never been disturbed in such manner. Emotionally unstable individuals are particularly susceptible to such situations. Resentment, irritation, anxiety, and other emotional states resulting from such situations are definitely known to retard the thought processes and interfere

with normal voluntary control over coordinated movements as required in flying.

e. There is no vocation in which the emotional factor plays a more important part than aviation. For when the military pilot is flying in aerial combat he is out of his normal element, surrounded by countless dangerous situations, his life and that of the crew depending upon an emotional stability which will insure proper reactions at times with lightning-like rapidity and precision. The modern pilot is, therefore, constantly under an emotional strain, and after a few years in the air he may find that he is a victim of operational stress unless he has used care and the greatest of judgment during his flying missions and normal routine of living. Deep in the subconscious mind of the airman the powerful instinct of self-preservation is always evident.

f. In addition to physiological considerations there are important psychological factors which are of great importance. The airman knows that at least twice a year, or more often, he must pass a physical examination which may ground him because of physical deterioration resulting from flying stress, minor accidents, or disease.

g. To relieve the pilot of mental worries a greater sense of security in his future and career is a very important consideration. The pilot realizes the hazards involved in the duties that he is performing and the possible deterioration resulting from his years of usefulness as a combat pilot. If he looks down through the clouds of gloom to a future ground assignment, with loss of air prestige or the possible loss of salary and flying pay, he will be affected mentally and depressed.

h. The professional pilot must be made to know that he will be taken care of by the service to which he has given the best of his life's efforts, mind, and body; he must know that he will be taken care of in a manner which will enable him to use his expensive, long career of training and experience in the same field of endeavor; that his career is not constantly in jeopardy; that as an aging pilot his training and experience still are immensely valuable to the service.

i. It is conceivable in some instances where inexperience cannot be blamed that an emotional strain may be the responsible factor for an accident through resultant errors in judgment and faulty control while under its influence. Emotional stability is extremely important in flying personnel. Above average emotional control must be maintained.

j. In the care and maintenance of the flyer, it is found that psychological fitness is very closely related to the maintenance of morale. The mental state involves many aspects of an aviator's activities, but

chiefly his work, his living conditions, and his recreation. The careful selection, training, and classification of the flyer are wasted unless he can be maintained in good condition to perform his flying duties in an efficient manner.

k. The element of subconscious tension is one which should always be faced with understanding. Failure to understand this is a possible cause of trouble in the families of the flying personnel. It is reflected in their contacts with other officers and men. It is reflected in the treatment of wives and children.

l. Wives at home have this same subjugation process to go through with, to as great degree as the airmen, as they have no feel of the ship to help them. They say good-bye in the morning and perhaps they are alone until night (expecting the commanding officer or medico to come in to tell of an accident). Many of these wives live constantly in the so-called "fear state." Often the excessive energy exhibited in the later stages of this phenomenon are reflected in the children. The fathers and mothers, trying to adjust themselves, communicate, unintentionally, their anxiety or symptom complex to the children.

63. Living conditions.—*a.* Adequate, roomy living accommodations with facilities for comfortable home life raise the morale of any individual. One's home should be a place where one may relax, where he may feel secure and free from the care of duty hours, and where he may pursue at his leisure his own hobbies and avocations of normal living.

b. There is an unsettled question whether or not it would be better for officers to get farther away from their work at the close of day, that is, for the pilot to live in a civilian community, out of sight and hearing of an airdrome and airplanes when not on duty. However, other factors, such as administrative details, economics, desires to be near friends and others of the same interests, make post life desirable and beneficial especially in times of peace.

c. Under greater stresses, such as in war conditions, it is not only desirable but necessary that pilots be quartered away from an airdrome. This may be in hotels or homes some distance from the airdrome, and it is desirable in such situations that the pilots get away from the flying fields as soon as official duties are completed.

64. Working conditions.—Even experienced pilots are undergoing a constant strain while in the air, although it may be unconscious. This constant strain results in great wear and tear on the nervous system. Unless the physical condition is kept up to a high standard they will become disabled for flying. Every effort is made to minimize some of these stresses by furnishing suitable protective equipment as well as proper working and living environment.

Section XII

PSYCHIATRY IN RELATION TO FLYING PERSONNEL

65. Problems of psychiatry in aviation.—*a.* The purpose of this section is to acquaint officers with the field, purpose, and problems of psychiatry, in its relation to aviation and maintenance of physical fitness of the flyer. The pilot will never be able to adjust mental difficulties by purchasing a standard remedy and following directions. The true remedy is prevention, and the individual must so live and conduct himself in his everyday life that there will be a minimum of unsolved conflicts trailing him. He must meet his everyday problems squarely, solving them honestly and satisfactorily.

b. Many problems may be of such weight and emotional coloring that the individual is unable to solve them unaided. It is then that the flight surgeon is of greatest value. He will be able calmly to discuss and advise, free from the emotional bias of the situation. This advice may save the individual needless worry, loss of sleep, the development of symptoms, or the adoption of bad habits, such as excessive drinking or the use of drugs as a method of escape.

c. The stable individual who lives a normal healthy life physically and meets his problems of home and duty fairly has nothing to fear from mental disease. The officer, like all people, is engaged throughout life in a continuous adjustment to his environment, an adjustment between desire and attainment, what he wants as compared to what he is able to attain, and all this within the sanction of the society in which he lives. If the adjustment is attained with a minimum of unsolved, avoided conflicts, the mental life will be a normal and healthy one. If conflicts are avoided through compromise and escape mechanisms, through flights into alcohol or illness, the end will be misery and defeat.

d. The flight surgeon stands ready, able, and willing to aid in this adjustment, recognizing danger and suggesting adequate remedy.

e. Psychiatry has a twofold mission in connection with aviation medicine: selection of the flyer and maintenance of his physical fitness. The primary concern here is with the actual care and maintenance of flying personnel. The flyer, like all men, is a composite of physical and psychic make-up, and each must be in order if the individual is to function efficiently. The mentally alert and stable indi-

vidual is of little value to the service if physically incapacitated because of a heart lesion, and the physically fit is of little value if he develops disorders of the nervous system. If the physically fit individual meets his daily conflicts involving duty, home, and family by the development of ailments, complaints, anxieties, and worries, he becomes of little value in combat aviation. Such conditions can never lead to efficiency, happiness, or mental health.

f. The military pilot must be well-equipped physically and mentally for his strenuous duty, for in his daily life he is subjected to more than the normal amount of physical and mental stress. The physical stress of flying under various conditions is well-known. The mental stress consists of various situations involving peace of mind. The combat pilot daily matches his precision and skill against severe injury or sudden death.

66. Psychiatry as applied to mental health in aviation.—*a.* Psychiatry as applied in aviation may be defined as that branch of medicine which deals with the origin, action, and results of disorders of personality, which either disturb the individual himself or his relations with other persons.

b. The cause of mental disease or disturbed adjustment is a complex one. Mental disease has been recognized since earliest times, and various causes have been listed, ranging from the moon through spirits, witches, and saints, and even to weather and the atmosphere. At the present it is known that there is no one specific cause for mental disease, but rather a combination of various conditions and complex situations.

c. The causes of mental disorders may be grouped under two headings:

(1) Predisposing causes, as heredity and environment.

(2) Contributing or precipitating causes or those situations which may actually precipitate a mental upset.

d. Flying personnel have been carefully selected, and for this reason the predisposing causes, heredity and environment, are less important. The factors to be considered are those stresses, conflicts, or complex situations which may actually produce a decrease in mental health.

e. Mental health and social happiness depend entirely upon the working and living environment and the individual's adjustment to the society in which he lives. Throughout life man is exposed to situations and experiences beyond his control, and these tend to develop a certain type of character, honor, ambition, and goal, which enables the individual to meet and adjust to association with other people. These various attributes are not standardized, however, and

as life progresses, situations become more and more complex, more difficult, and thus an even greater adjustment is necessary. Certain personalities are readily able to meet these stresses and remain stable, well-adjusted individuals, while others find conflict or discrepancies between desire and attainment. These conflicts must be met and handled in a way acceptable to society and the solution must have the approval of associates. The unstable individual finds it more difficult to make the adjustment and must have aid and guidance, lest a method of adjustment be upset (a solution to his conflict) which may lead farther and farther away from society as a whole. This condition may develop in the form of avoidance by focusing attention on personal worries or physical symptoms, as seen in nervous disorders.

f. The individual may avoid unpleasant situations by a "flight from reality," by the excessive expenditure of energy in nonessentials as in manic phase of manic depressive mental disorders, while in the depressed phase they tend to approach a dormant condition, completely overwhelmed by the ordinary experiences of life. There are other types who seek to avoid painful experiences by shifting the blame to others, and shield their own personality from painful stress by projecting their problems to others. There are also personality types who, overwhelmed by their conflicts, retreat from reality completely and find shelter in the phantasies of a make-believe world where infantile memories control their interests.

g. There are many actual precipitating causes for mental disease, but only a few mentioned herein. In the realm of disease, the best known cause is syphilis, and though many lay ideas regarding the disease are fantastic, syphilis is an important factor in producing mental disease. The various bacterial diseases, too, play a part in the production of mental disease.

h. The actual mental derangement that the layman calls insanity consists of many varied conditions, ranging through loss of mental powers to the effects of disease and age, and including many well-known conditions as mental depression and the various alcoholic and other toxic derangements.

i. These conditions are important to officers and men in aviation, because the efficiency of the service, in fact, their very lives, may depend upon the early recognition of mental disorders. The flight surgeon is able to recognize these conditions and institute proper treatment, in some cases aiding with proper adjustment; in others, removing the individual from hazardous duties.

j. Unfortunately, it too frequently happens that a flyer suffers a mental break-down, but is seen by the Medical Department only after

he has committed some act of damage to himself or others. This can be avoided in most cases if the surgeon gets the history before the actual break occurs. This requires the cooperation of the families and of associates. An officer should not hesitate to tell his flight surgeon that a brother officer and good friend is "acting queerly"—perhaps a change in disposition, increase or decrease in activity, sleepless nights, rapid changes in mood, sudden outbursts of violent anger, feeling blue, or any deviation from that individual's normal personality. No officer would hesitate to call the surgeon's attention to his friend's severe cough or frequent nose bleed; why, then, should he hesitate to discuss queer behavior with a medical officer?

k. The individual may be flying much against the wishes of his wife or family, and the knowledge of this situation may disturb him, consciously or unconsciously. Any or all of these situations (conflicts) may cause the individual to seek a solution which is not conducive to efficient flying.

l. The pilot may fly a minimum amount, thereby causing a minimum amount of concern to wife and family. Yet he is not satisfied with such a solution because he recognizes it as a compromise and, too, the limited flying does not satisfy his desire or his ego; likewise his efficiency report and general standing in his career may be a source of mental anguish. Situations of this kind are not uncommon and often lead to various escape mechanisms, such as overindulgence in alcohol. The individual finds that he is free from care and worry while indulging in an alcoholic bout. This again is only a temporary solution and one which cannot go on if the pilot is to continue a successful military career.

67. Psychiatry and use of narcotics.—*a.* Alcohol too frequently appears as the solution to conflict and is always a false refuge. Alcohol used as a "crutch," as an escape or flight from reality, leads only to misery and defeat.

b. Drugs and poisons play an important part and undoubtedly alcohol is the most important. Alcohol when properly used may play an important and satisfactory part in the life of an individual, or it may in other persons be improperly used and lead to degeneracy, criminality, and misery for the user and his family. Other drugs such as morphine, cocaine, or marihuana play lesser roles in the production of mental disease. Precipitating causes also include disturbances of the glands of internal secretion, epilepsy, arteriosclerosis, permanent injury, and even to premature aging, which is often contributory in the production of mental illness.

SECTION XIII

SELECTION OF FLYING PERSONNEL AND MAINTENANCE OF PHYSICAL FITNESS FOR FLYING

68. Elements and functions of human body.—*a. General.*—The body is in reality a living machine. The structure and functions of the body as developed by evolution are in accord with the environment and use to which subjected. The combination of structures which make up the body as a whole is the result of coordinated and accurately proportioned activities that, when taken together, constitute the life of the human individual. After these activities are analyzed it is found that an amazing number of complexes and activities are often conflicting which develop out of the stimuli and the environment of the individual. Action is absolutely essential to life. One does not think of life without some kind of action. The greater and richer the life, the higher the degree, quality, and complexity of action.

b. Study.—The study of the body can be divided as follows:

(1) The subject of *anatomy* includes the *structure* of the body and its organs.

(2) The subject of *physiology* includes the *functions* of the body and its organs.

(3) The subject of *hygiene* includes the understanding of both *anatomy* and *physiology*, so that it is possible correctly to maintain the physical fitness for normal activities and to conserve body energies.

c. Functions.—Some of the fundamental vital functions of the body are listed as follows:

(1) Sensation.
(2) Motion.
(3) Nutrition.
(4) Respiration.
(5) Reproduction.

d. Senses.—The five senses of the body are—

(1) Sight.

(2) Hearing.
(3) Smell.
(4) Taste.
(5) Feeling (touch, pressure, pain, hot, and cold).

e. Special senses.—In addition to the senses mentioned, hunger and the function of balance or spacial orientation are often considered as additional special senses.

f. Blood and its functions.—The blood is a fluid kept in circulation by the heart. The blood flows through a series of tubes known as the arteries, veins, and capillaries. Some of the functions of the blood are as follows:

(1) Carries the food after it has been digested and prepared for consumption by the organs of the body.

(2) Brings oxygen from the air into the lungs.

(3) Carries away the waste products of combustion or metabolism.

(4) Distributes the various secretions of the glands and internal organs.

(5) Helps maintain the temperature of the body.

g. Nutrition and heat.—(1) Carbohydrates when digested furnish quick heat and energy.

(2) Proteins furnish some energy, but their main use is to build up tissues of the body.

(3) Fats furnish the greatest amount of heat and energy per unit of weight.

(4) Vitamins are chemical substances essential to life itself. They act as regulators of the various chemical reactions in the body. They are present naturally in certain foods, and several of them have been made in the laboratory and are available in the pure chemical form.

(5) Heat and its regulation can be tabulated under the following headings:

(*a*) Heat is produced as follows: By oxidation of food and as a byproduct of exercise.

(*b*) Heat is lost mostly through excretion, expired air, perspiration (evaporation), and convection.

(*c*) Heat is regulated by a heat control center in the brain to which sensations are transmitted from the various areas of the body.

h. Food and digestion.—The first steps in digestion occur within the mouth from which food passes into the stomach. The stomach of man is a single organ in which food is received and temporarily stored during the second step of digestion. After leaving the stomach, food passes through the small and large intestines, shown in figure 32. The most important part of digestion of food is completed in the

intestines and from there most of it is absorbed. A complete discussion of digestion is not within the scope of this manual.

i. Liver.—The liver performs an important function in the nutrition of the body. Its function is to secrete the bile. The bile has many functions but the most important is the part it takes in the digestion of fats. It has other functions, among which is included production of substances to aid in coagulation of the blood.

j. Kidneys.—The kidneys are responsible for separating the waste elements from the blood. The process is partly filtration. Drugs,

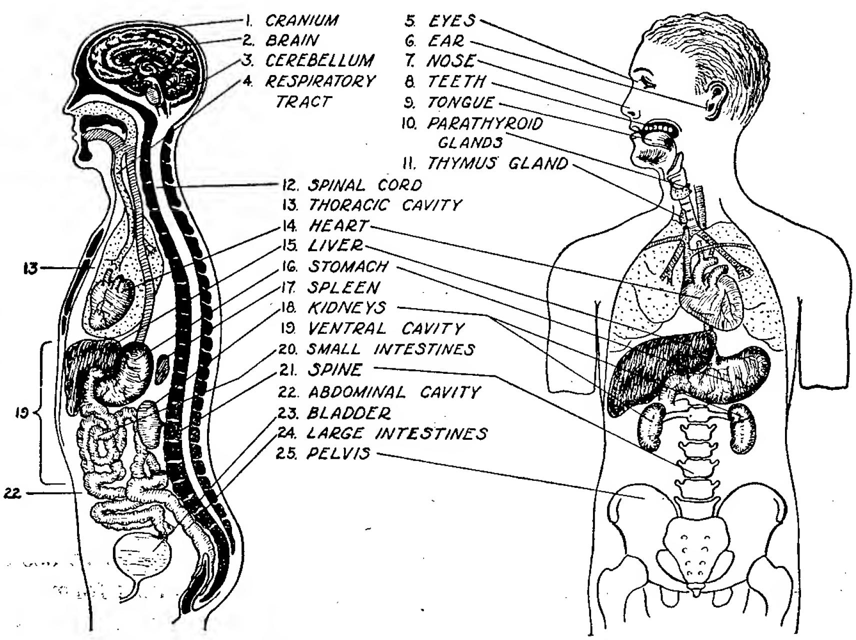


FIGURE 32.—Important parts and organs of human body.

bacteria, and most waste materials are thrown out of the blood by the kidneys. Some waste materials are also eliminated by means of perspiration.

k. Other organs.—Some of the most important organs of the body are named and illustrated in figure 32. It is not within the scope of this manual to discuss each of the organs of the body and their normal functions and an attempt is made only to discuss very briefly the most important.

l. Eye.—In many respects the eye can be considered the most important sense organ used in flight, as the loss of vision would imme-

diately place the airman and his crew in a most hazardous predicament. The functions of the eye are explained as follows:

(1) The eye in many respects can be likened to a camera. It is impossible to obtain a perfect photograph if a perfect lens is not provided. Similarly, normal vision is only possible if the lens of the eye is relatively perfect. In aviation vision must be normal or better, without glasses. The total extent of the field of vision is also of importance. The ability to recognize and distinguish between colors is very important to the pilot and observer.

(2) The eye can be likened to a camera in another respect, as each eye must be focused to the approximate distance if a clear, sharp image of an object is to be produced and seen. This is achieved in a camera by altering the distance between the lens and film, but in the case of the eye the shape of the lens itself is changed through the action of the tiny muscles located within the eyeball. This process is known as "accommodation." Accommodation is important in flying because the pilot is continually changing the focus from his instruments and charts to objects in the far distance.

(3) The two eyes do not see an object from exactly the same position. Therefore, the images they form of it are not identical. This results in stereoscopic vision and helps in the estimation of depth or distance.

(4) There are many other important considerations, such as night blindness, the effects of altitude, fatigue, the effects of carbon monoxide or other poisons on vision, and the speed of visual perception.

(5) Good vision is essential because the airman in take-off, landing, observation of instruments, and in formation flying must constantly watch the sky for other airplanes and must be able to see the ground and make observations clearly. When two airplanes are traveling toward each other at 300 miles per hour or more, the time elapsing after they are sighted until they meet is extremely short, hence it is necessary that the eye pick them up as early as possible. This is especially important in combat.

m. Ear as sense organ.—(1) The ear and its inner mechanism serves both as an organ of hearing and as one of the organs regulating balance. The ear in relation to balance has been previously discussed. Upon returning to the surface after long flights most airmen are affected by a reduction in hearing. The hearing is affected to a minor extent by changes in atmospheric pressure in ascending to and descending from high altitudes, but to a greater extent by the noises to which the airman is subjected while in flight. The noises affecting hearing in flight are chiefly motor and propeller noises, the rushing of air

past the airplane, and radio noises in the headphones. The radio should not be tuned so high in volume as to be of sufficient magnitude to affect the hearing at the end of the mission. The external noises can be reduced by the use of cotton plugs inserted in the ear. The use of ear plugs made of hard rubber or wax should not be adopted as injury to the ear is apt to result. The ear is anatomically divided into three divisions, as shown in figure 33, as follows:

(*a*) Outer ear or canal (up to the ear drum).

(*b*) Middle ear (air space behind the ear drum).

(*c*) Inner ear, including the mechanisms of hearing and balance.

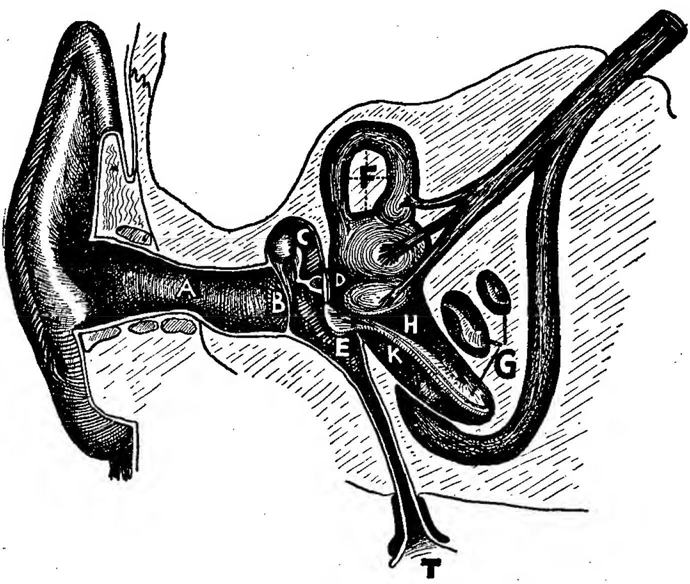


FIGURE 33.—Section through right ear, showing organs of hearing, sensation, and balance.

(2) The space in the inner ear is in communication with the outside air by means of a passage which ends in the back of the throat. The air spaces known as sinuses are also in communication with the outside air by means of small openings into the nose. Due to the differences in pressure produced air rushes out of these partially enclosed areas during ascent and rushes into them during descent, and in this way the equalization of inside and outside pressure is maintained. Any condition which interferes with this free equalization of pressure should be avoided. In a rapid descent the rush of air through the nose and throat may take infected material into the inner ear or sinuses, resulting in middle ear disease or sinusitis. Therefore, flyers who are suffering from colds and sore throats should not fly, or at

least should not fly at high altitudes or make rapid descents. The sudden closure of these openings during descent causes excruciating pains and even rupture of the ear drum has been recorded. When forced to fly with an inflammatory condition of the nose, the use of soothing ointment containing a drug which shrinks the membranes of the nose is useful and may prevent the onset of ear or sinus disease. The structure of the mouth, nose, and throat is illustrated in figure 34.

69. General considerations of physical fitness.—*a.* In a general sense physical fitness infers good health. The healthy individual is able to combat adverse influences and to react to the conditions of

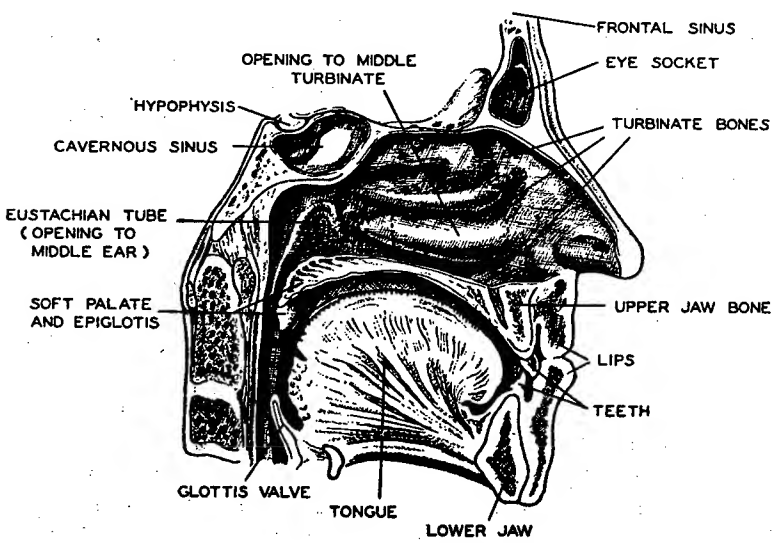


FIGURE 34.—Section through mouth, nasal passages, and throat.

his external environment in such a manner that the physiologic processes of his body do not lose their qualities of adjustment and do not disturb or modify the internal functions.

b. Man is born into the world with a body equipment which enables him to meet the problems of life. This equipment may be poor, average, or excellent, but its eventual service to him will depend on how well he builds upon it and utilizes the combination of his hereditary and acquired resources.

c. The equipment of the body may be divided into three main categories as follows: physiologic, psychologic, and morphologic.

(1) The physiologic is the basis upon which capacity for activity is enlarged and qualities of adjustment obtained by means of graded and frequent use of the organs.

(2) The psychologic is the realm of the mind which, as ma
the body machine, acquires greater capacity and a better equil
and adjustment with progressive and appropriate use.

(3) The morphologic is made up of the physical form and
ture of the body and is largely determined by heredity.

d. In proportion, as these three categories are properly dev
and maintained, there are created preparedness for activity an
tive freedom from fatigue. When these conditions obtain, th
good health of some comparative degree.

e. One's interest in physical fitness and health must go deep e
to help avoid illness and postpone death. It has been said th
ideal goal is to be sufficiently fit to accomplish each day's work
minimum of fatigue and to remain active until old age. This
factory attitude toward life will naturally be predicated upon
born and acquired equipment of the individual. There are som
will be compelled to train for heavy physical work to attain
goal, while others will reach it better by choosing light work.
ever the individual's incentive or ambitions may be, life should
ordered that the body maintains its normal physiologic status.
there is failure to do this, pathologic conditions result and the
becomes unhealthy. A low degree of health or fitness leaves no m
of safety for the experiences of adversity which so frequently d
unexpectedly.

f. (1) Four criteria of fitness are listed as follows:

(*a*) The chemical processes of the body should proceed in an o
manner.

(*b*) The structure and power of the body should be adequ
meet ordinary needs and to supply sufficient reserve for un
demands.

(*c*) The organs of sense should accurately record the sensation
impressions received.

(*d*) The nervous system should properly interpret the sens
received from the sense organs and initiate the proper physical res
for preservation of the body in its struggle with its environment.

(2) These criteria lead to the assumption that the important
in physical training of Air Corps personnel is not the developme
big muscles and athletic prowess, but the attainment of physica
mental efficiency so as best to cope with the demands made on the
in its struggle against its surroundings.

g. The aids which bring this about are the proper selection of
rest, exercise, and environment. In daily environment and occupa
there are often factors which may tend to counteract this proper

tion and reduce vitality. Therefore, should such detrimental
arise, a well-selected course of physical training will go far i
them.

**70. General physical requirements and physical f
flying.**—*a.* The subject of general physical fitness and re
for flying includes practically the study of the entire huma
the most important considerations are the heart, lungs, dig
tem, blood, nervous system, and the various senses and sens
For efficiency it is not sufficient to say that our pilots must
or even stale. They must be in a physical condition compa
athlete in good form. The demand on pilots for grea
strength is not as important as endurance, stability, and th
quick thinking and reaction. In fact, large bulk may b
liability as the best pilots are often found to be of a wiry r
either a muscular or beefy type. Resistance to psychologi
as physical strain is of great importance. Many young m
found physically fit are eliminated from flying training bec
proper psychological reactions. They are considered tempe
unfit for flying duty.

b. Maintenance of the physical machine should be secure

(1) Periodic medical physical examinations and advice

(2) Attention to general living conditions and the co
environment in which work is carried out.

(3) Avoidance of continuous overwork and proper rela
recreation.

(4) Exercise of care and proper protection in air exper
prolonging the flying life of the flying personnel.

c. It is necessary that pilots and other flying personnel
maintain the following:

(1) Good, sound, normal physique as a basis for their wo
when necessary normal strains and fatigue may be met w
factor of safety.

(2) Not too sensitive temperaments, so that sudden dem
the individuals do not produce overaction or faulty respon

(3) Reasonably abstemious habits as regards food, hour
drinking, smoking, and general living.

(4) A desire or willingness for exercise. Free movemen
tial if all parts of the body are to function properly, the e
the circulation being dependent upon adequate muscular
and tone.

d. It is essential, after careful selection and classificat
flyer, that his physical fitness for flying be maintained at t
state of efficiency. In military combat operations there i

strain, physical and mental, associated with flying. Just as it is the duty of the Medical Department to care for troops at the front and restore the disabled to the fighting line as soon as possible, it is the duty of the flight surgeon to keep flyers in condition to fly and to restore those temporarily grounded to a flying status as soon as possible. To know and understand the physical factors concerned in flying, the flight surgeon must have a general knowledge of operating conditions and the responses and adaptations of the human body to these factors.

e. Periodic physical examination of flying personnel provides information useful to the flight surgeon and flying personnel for the conservation of health. The airman would hardly fail to demand that his aircraft and equipment be given periodic inspections. It should be emphasized that the human element in flying is much more subjected to the effects of flying and to deterioration than the mechanical flying equipment. The failure of flying personnel to perform efficiently one aerial mission may have disastrous military results, and one crash prevented may save several lives and thousands of dollars worth of equipment.

f. Every mission of an airplane which is completed successfully means that the machine and its engine have functioned properly, also that the pilot has not failed to execute the necessary functions of control. Experience has taught the importance of correcting mechanical defects and preventing failure. The application of knowledge of the human element is of even greater importance. The engine or parts of the airplane may fail to function while in flight and yet by skill the pilot may make a safe landing, but if the human engine fails completely in the air in all probability a fatal accident lies ahead.

g. The health of the pilot and the flying personnel is, therefore, the final determining factor or keystone of combat aviation efficiency. In flights of all descriptions in good and bad weather, in take-off and in landing, it is the human machine that has so rapidly increased safety in aviation, both military and commercial. The credit for this lies chiefly with those responsible for the selection of the right type of young personnel to be trained for this work.

h. Data curves available demonstrate that pilots maintain a physical condition above the normal for their age and one should, therefore, be able to look forward with confidence to efficient piloting up through the age which is generally known as the prime of life. However, this is only possible through personal indulgence in observing proper care and habits throughout the years of flying.

i. It is possible for all alike, air personnel and flight surgeons, to help in conserving health, the most valuable asset of everyone. It

can be said from the evidence now accumulated of the physical condition of pilots, both civil and military, some of whom have been flying normally for 20 years and even longer, that there is no sign of *abnormal* deterioration in those with reasonable habits who have observed rules of normal living set forth herein. Flying personnel may look forward to the normal expectancy of life in time of peace by strictly observing normal living conditions and by proper application of the knowledge available.

j. Age has become an important factor in combat, operational flying. Many of the first pilots who flew during the World War are still engaged in flying after more than a score of years as pilots. Reaction time becomes slower as one grows older, though this slowing down process varies in different persons. With increasing age, particularly past middle age, there is a lessened plasticity of the faculty of learning and retention, as well as tolerance and open-mindedness. Habits of long duration guide and fix much of one's activity. The biologic modifications of aging also demand a general slowing down with fewer hours of application, greater deliberation in execution of duties, and a slower cadence of activity. This factor of age is one which is receiving more and more attention and should be given definite consideration commensurate with specific types of flying duties.

71. Flight surgeon and functions.—*a.* Medicine has become universally important in aviation for the selection and maintenance of physical fitness of flying personnel and for continuous research into the many problems of the physiological aspects of flying. Doctors specializing in the subject of aviation medicine are designated as flight surgeons. It is indisputable that one should be well acquainted with aviation to be able to judge of the fitness of candidates for flying.

b. It appears that the rules relating to fitness should be based on facts derived from the experience of pilots and members of combat crews, as well as from experimentation in the subjects pertaining to the physiological aspects of flying.

c. The work of the flight surgeons is not confined to the mere routine examination of flying personnel; they are likewise concerned with the operating conditions and general life of those associated with flying, as well as the general questions of hygiene and health that help to specify and provide comfortable living and working conditions and general healthful surroundings.

d. Each flight surgeon should be a man of vision and imagination, specially trained and highly educated in the very important functions of the service in which he is required to serve.

e. The first important duty of the flight surgeon is to select from the many applicants those young men whose physical and psychologi-

cal qualifications promise the best possible odds in favor of their success in aviation. After selecting the applicants he watches them through their courses of training and he exerts his influence to see that they remain physically and temperamentally fit for the hazardous duties that may be essential during the various flight missions. The flight surgeon will recommend that flying training be temporarily discontinued whenever he considers a student or pilot physically unfit or mentally fatigued to such an extent that he is not efficiently performing his duties and has become a danger to himself and others.

f. The subjects of first importance which concern the flight surgeon may be tabulated as follows:

(1) Examination and selection, including the physiological and psychological considerations, of flying personnel.

(2) Life and environment of flying personnel, including questions of hygiene and health.

(3) Flying conditions and hazards of aerial operations to which flying personnel are subjected.

(4) Precautionary advice and instruction.

(5) Preventive and corrective advice and instruction.

(6) General aspects of medicine, particularly those applicable to flying personnel. A point of great importance is the prolonging of the longevity of the flying personnel.

g. Flying personnel should not hesitate to go to the flight surgeon for advice and to follow carefully the advice received. By doing so the flying personnel will receive the following definite advantages:

(1) Early diagnosis of disease or deteriorating factors, enabling their correction before permanent damage is done.

(2) Advice and guidance, enabling them to retain physical fitness or to regain fitness if it is deteriorating.

(3) Proper knowledge of their physical condition that may help to prolong the flying period of life and keep them physiologically youthful for many additional years.

h. Whenever the name "flight surgeon" is mentioned among flying personnel, particularly pilots, it is not unusual for them to feel a slight chill run up and down the spine, as each airman is often fearful of his physical condition and that the flight surgeon may sooner or later find some ailment which may incapacitate him for flying duty. However, this condition of fear should not exist as the flight surgeon should be and is truly the best friend of the flying personnel.

i. The objective of the periodic physical examination is not only to determine the health of flying personnel and to advise them, but also to eliminate airplane accidents and to conserve personnel and equip-

ment. Accidents will be greatly reduced if all of the risks of flying from physical and other causes become known and corrective action is taken.

j. Research into the physiological aspects of flying has been intensified in aviation because of the professional appreciation of the necessity for conserving personnel and matériel. There are many alarming reports of abnormal crashes which have occurred in Europe during progress of the war. These reports have indicated that pilots returning from extended bombing missions have crashed on their own airdromes, in the sea, or near home upon nearing the completion of their missions and after apparent danger had passed. Many abnormal errors in combat, such as improper aiming of bombs and incorrect tactics while engaged with enemy fighters, have occurred. The loss of skilled, trained, and courageous personnel and valuable equipment has been so impressive that the search for the causes has been intensified, and an effort is now made to avoid these losses and bring facts and lessons learned to the attention of flight surgeons and flying personnel.

72. Selection of flying personnel.—*a*. One of the important problems of military aviation medicine is the development of an improved means of selecting candidates for flying training to insure the Government against the expense of sending candidates to training centers who are incapable of completing their flying training by reason of physiological or psychological inaptitude.

b. The search for means or methods by which the inherent ability for combat flying can be identified is one of the hardest problems facing the flight surgeon. Even where the applicant possesses all of the physical specifications required, this is not a guarantee that he will become a good fighter for there must be a will or willingness for armed conflict—"a soldierly spirit." The fundamental qualifications which include age limitations, examination of the body, and psychological survey are comparatively simple and eliminate a large number of the obviously unfit. However, the tests so far conducted will not prove conclusively which of the applicants can become reliable military pilots and which cannot. The racking physical, mental, and nervous strain of aviation performance in war demands a singular aptitude.

c. The physical examinations required for other branches of the military service do not suffice for those in the flying arm. At the present time it is often stated that a flyer in time of war is good for only about 150 hours of flying on combat missions before he is affected by flying fatigue or operational stress which affects him physically

and reduces his efficiency. The British have found that a large percentage of their casualties were the result of physical defects or of the physiological aspects of flying compared with a very small percentage resulting from action of the enemy. The adoption and the development of a service for maintenance of physical fitness by proper medical supervision have resulted in a great reduction in losses of personnel.

d. It is obvious that a tremendous saving of time, manpower, equipment, and money can be effected by eliminating at the source material which is unfit for flying. Among other qualifications an aviator must be stable and courageous. He must possess good judgment, intelligence, enthusiasm, and he must be responsible and adaptable. His reaction time must be at least normal, memory and attention must be good, he should be aggressive, alert, self-possessed, a good sportsman, orderly minded yet not to extremes of introversion.

e. Each airman must make a study of his own reactions to the conditions imposed upon him in flight and attempt to analyze them by his knowledge of the factors affecting him, with the advice of his Army doctor who is a specialist in the subject of aviation medicine.

f. Safety and conservation in personnel and matériel are, in part, attributable to careful medical examination and selection of personnel. But no matter how carefully personnel are selected, accidents causing the destruction of equipment and the loss of life will occur. These must be kept at a minimum by a knowledge of the conditions and dangers encountered and application of all precautionary measures by flying personnel.

73. Importance of muscular exercise.—*a.* Proper exercise is an absolute necessity for physical fitness. This assertion is based on the fact that use makes and develops an organ and disuse means staleness or decay.

b. The organs of the body require exercise which is needed for the maintenance of health. Unless these are used they become a source of weakness. The muscles of our bodies are usually far in excess of normal requirements. The amount of lung surface and heart tissue is more than is required. In the central nervous system a large portion is set aside for the control of muscular activity, and this must be used to keep it functioning properly. Therefore, a considerable factor of safety is provided in the human body.

c. The aims of exercise are to remedy pathological conditions, to influence growing conditions, to aid in the development of structure, and to maintain vigor and produce resistance to fatigue, disease, etc.

d. For the maintenance of vigor, the amount of exercise taken need not be great. It should, however, be sufficient to produce general effects and to place real demands on the respiratory, circulatory, and heart regulatory mechanisms.

e. Five groups of muscles induce the general effects of exercise. These are the flexors and extensors of the thighs, the abdominal and back muscles, and the shoulder muscles. The general effect is not well obtained if one group alone is favored.

f. The gain in muscular power is out of all proportion to the gain in size of muscles. It is evident that training improves the quality of the muscle contraction. This improvement in quality may be associated with an actual change by which fuel is made more available and stored in greater amounts, and oxygen is more abundant due to a better circulation of the blood.

g. There are certain well-defined changes in the respiratory mechanism and its functioning brought about by muscular exercise of physical training. The expansion of the chest is increased, the rate of breathing is slowed, and the depth of breathing is augmented. Muscular training renders the entire lung volume readily accessible, so that the blood may be exposed to oxygen over a much greater lung surface.

h. The inefficient individual has very little movement of the diaphragm and breathes with greater respiratory frequency. The athlete possesses a deep diaphragmatic breathing and a slower breathing frequency. Figure 35 includes three curves giving values of blood flow, ventilation, oxygen, and work in kilogram meters per minute.

i. Lung capacity cannot always be judged by external measurements of the chest. Youth is opportune time for chest development because exercise results in enlargement of the chest during growth and influences the size thereafter.

j. Trained men breathe less air and absorb a greater amount of oxygen from it during muscular exercise. An anlysis of samples of exhaled air shows that trained men absorb a greater amount of oxygen than untrained men, which means that the breathing becomes more economical after a period of muscular exercise and training.

k. Circulation of the blood through the tissues supplies oxygen and nutriments to them and removes from them lactic acid, carbon dioxide, and other wastes. Circulation of the blood is an important factor in the ability of an individual to respond to requirements of physical exertion. A period of physical training improves the ability to increase the volume of blood-flow and renders the heart more efficient.

l. Since the athlete has a stronger heart and for a given venous pressure the output per beat is larger in the trained than the untrained

man, given a larger stroke per beat and a slow pulse rate, the system of the athlete is enabled to transport oxygen more readily.

m. Physical conditioning is recognized by the time required for the pulse rate to return to normal after exercise. The athlete shows a rapid return and possibly a subnormal reaction; the inefficient man is slow in his return to a normal rate.

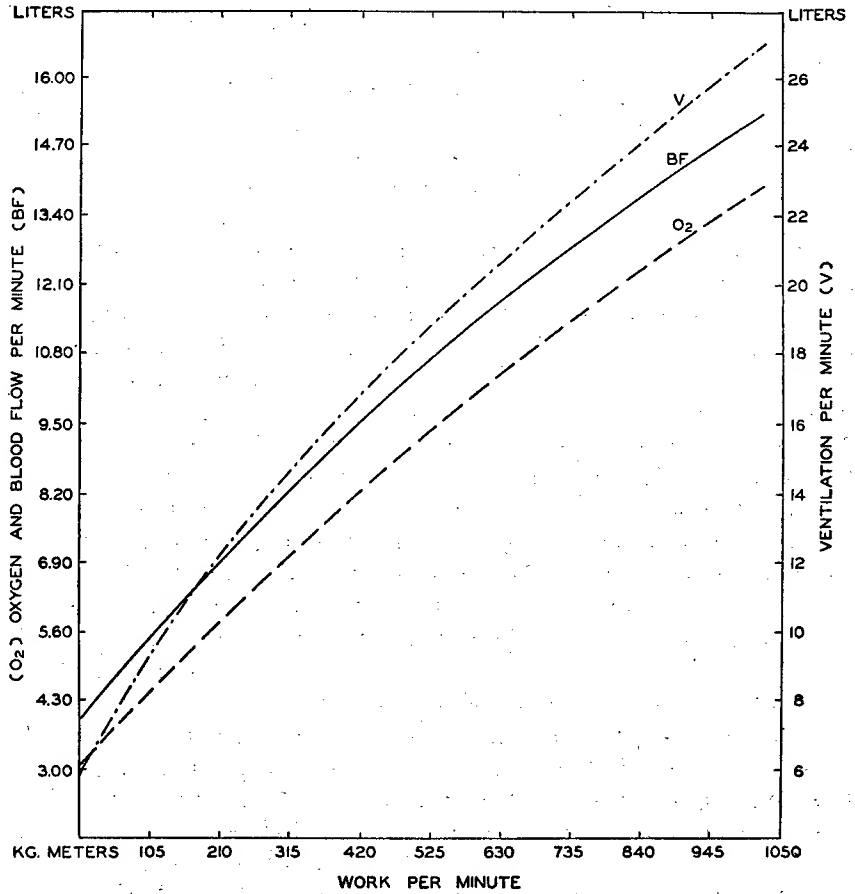


FIGURE 35.—Curves of blood flow, ventilation, and oxygen according to variation with work.

n. The opinions of today regarding the heart in exercise are summed up as follows: Carefully graduated exercise improves the nutritive condition and develops the muscular power of the heart at the same time it develops the skeletal muscles. The weight of the heart is directly related to the general development of the body muscles. When a heart functions well it has a highly efficient coronary circulation.

Observers believe that with better functioning there is either a formation of new capillaries or the opening up of hitherto unused capillaries. These various changes allow the heart of the trained man to empty itself more completely than the weaker heart of the untrained man.

74. Occupational fatigue and flight stress.—*a.* Fatigue is a condition which all have experienced in one form or another. Its symptoms are easily recognized. There are innumerable factors in relation to flying which operate to bring on fatigue many of which have been discussed in previous sections of this manual under the various headings included in the physiological aspects of flying. Fatigue is intimately associated with emotion so that the amount of fatigue that is actually felt is not proportionate to the work that has been done. Under high emotional strain and incentive much more work can be done and the resulting fatigue will be less than would be expected.

b. Fatigue is a condition which produces a demand by the body for rest, that is, a chance to rebuild those portions of the body which were used up during work done and during nervous strain. Muscles, through continued action, can be fatigued under extreme conditions to such an extent that contractions of these muscles are no longer possible. However, the sensation of fatigue will develop long before this stage is reached, and unless there is an emotional incentive or unusual will power is exercised, an individual will voluntarily stop the work or contraction of the muscles long before the stage of muscular paralysis is reached.

c. The paralysis of the muscles under such condition is due to the fact that the chemical processes incident to the production of energy or work have used up the reserve chemicals and energy in the muscle substance and there has been an accumulation of waste products in the muscle cells. The muscles must then remain at rest until the chemical processes which repair the muscles have had a chance to catch up and the excessive waste production carried off by the blood-stream. This accounts for the fact that after strenuous and unusual exercise which normally would leave one sore and painful, if the body is thoroughly and properly massaged, the blood circulation is stimulated and the expected amount of soreness and stiffness does not occur.

d. In addition to this type of fatigue, with which all are familiar, there is another type of fatigue, called emotional fatigue, which is all out of proportion to the amount of physical work done. An ex-football player sitting on a bench watching his old team play a hard game against a traditional enemy will be tired at the end of the game even though he did not actually engage in the physical combat. Emotional strain and tenseness can cause a fatigue that is as real as that caused by actual overuse of the muscles of the body.

e. There is a limit to our physical capacity and there is also a limit to the amount of nervous strain and stress that any individual can endure. It might be said that it is possible for one to become emotionally paralyzed as well as emotionally fatigued. Assuming that there is a limit of both physical and emotional endurance, it behooves those in authority not to let the individual reach either of these limits. Just as the muscular system works more efficiently and lasts longer if periods of rest are taken and the chemical processes allowed to repair the muscles, so our mental and nervous system works more efficiently and lasts longer if the strains are removed periodically.

f. Under the strains and stresses of flying, whatever their cause, be it too long hours or unusual and hazardous experiences or fatigue due to excessive muscular exertion, or a combination of these and many other factors, there comes a time when the cumulation of fatigue will cause the appearance of abnormal symptoms. If these strains were allowed to continue indefinitely and no opportunity were given to make proper readjustments, eventually there would come a time when the individual would break. If the individual were allowed to come to this condition, it would take months and perhaps years for him to become normal again and he might possibly be permanently incapacitated.

g. The symptoms of fatigue show up long before the muscle is paralyzed. Likewise, symptoms of strain and stress appear before the advent of nervous break-down. Much has been said in the past about staleness or flight stress among flight instructors and it is known that the treatment has been the removal of the cause. This was accomplished by allowing the instructor to go to the seashore, the mountains, or some other place of rest out of sight and hearing of all things pertaining to flying and affording him an opportunity by means of rest and recreation to become physically fit again. During the last war it was soon noticed that pilots engaged in combat reached a state in which they were both physically and emotionally unfit, and it became necessary to send them back from the combat area and allow them rest and recreation in order to regain their physical fitness. The warning symptoms of excessive strain or stress may be of a varied nature. The chief symptoms are usually excessive fatigue, increased irritability, loss of appetite, disturbances of digestion, loss of weight, and insomnia, and the sleep when obtained may be disturbed by violent and terrifying dreams. In any individual case only one or all of these symptoms may appear.

h. The prevention and treatment of this condition are the same; the only difference being that the condition is much more easily pre-

vented than cured. In order to prevent this condition from arising, it is essential that the individual be in the best possible state of physical health, and adequate time must be provided for his body and nervous system to repair the damage incident to the strains and stresses of flying. This is done in time of war by limiting, within a given period of time, the number of flying hours; by limiting the number of missions; by providing for the bodily comfort, rest, and recreation of the individual between missions; by doing everything possible to keep him physically fit, and by removing as far as possible, all extraneous causes of emotion and conflicts, such as worry over the economic condition and safety of his family or loved ones back home.

75. Effects of tobacco, drugs and alcohol.—*a. Tobacco.*—Men living under the strain of war conditions may use more tobacco than normal. This may apply particularly to the aviator during war, for he frequently has long hours of waiting on the alert for combat missions. The cigarette is smoked by most men in the flying service and some inhale the smoke from 20 to 40 cigarettes a day. The effect of smoking this number of cigarettes daily is unquestionably harmful. In general, it may be said that the inhaling of smoke of several cigarettes or one cigar appears to impair some of the functions of the body. However, these effects may pass off rapidly after smoking. The effect of smoking while in flight or an excessive amount of smoking prior to flight may have considerable bearing upon the fatigue factor and upon the ability to withstand the conditions of high altitude, and result in slowing the normal reactions when they are most needed.

b. Drugs.—The use of drugs except as medicine prescribed by a physician must be avoided by flying personnel. Harmful effects can be expected from such drugs as quinine, aspirin, phenacetin, bromides, alcohol, and others. Some of these are often taken as an ill-advised remedy for airsickness and nausea after returning from air missions.

c. Alcohol.—The use of alcohol is a very important consideration for flying personnel. After the strain of flying, particularly after combat missions, there is often a tendency to take a drink, which may lead on to the consumption of several more. There are a number of facts of outstanding significance which should be impressed upon those using alcohol.

(1) Alcohol has some food value for the immediate use of the body but it is not stored for future use like most other foods.

(2) Whatever food value may be contained in alcohol is largely counteracted by its drug action.

(3) Alcohol is absorbed into the blood stream very rapidly from the stomach and intestines. Therefore, it is quickly distributed

throughout the blood and organs of the body, particularly the brain and spinal cord.

(4) The rate of removal of alcohol from the body is almost constant and is not greatly increased with exercise.

(5) The action of alcohol on the tissues is to impair the utilization of oxygen by the body.

(6) Alcohol impairs sensory, motor, and mental functions and acts as a depressant on the nervous system.

(7) Alcohol has a serious effect on the flyer and his higher faculties, and particularly prevents close attention and concentration.

(8) The airman must keep continually in mind the great danger to which he is subjecting himself when starting a flight, particularly to high altitude, where there is alcohol still in his system.

(9) Alcohol prevents proper adjustment to the conditions at high altitude, of low barometric pressure, and oxygen deficiency. The effects of oxygen-want at high altitude are very similar to the effects of alcohol, which produces intoxicating effects, leaving flying personnel incapable of making critical judgment on one's own behavior or the actions of others.

(10) The use of alcohol for flying causes a dangerous situation, that is, the effects of two types of oxygen-want at the same time. One is due to the lower oxygen supply in the atmosphere and the other is due to the action of alcohol in preventing the amount of oxygen available from being absorbed by the tissues from the blood stream.

(11) From many investigations which are accepted as conclusive, it can be stated that alcohol in the blood stream and spinal fluid impairs the normal functioning of the body, particularly the mind and nervous system.

(12) It is not only the immediate effects of alcohol which are dangerous, but there may be permanent after effects which may shorten the flying life period and lower the flying efficiency.

76. Prevention of cold and other communicable diseases.—*a.* To avoid colds, influenza, and other communicable diseases—

(1) Avoid crowds.

(2) Avoid the cougher and sneezer who sprays one with material loaded with germs.

(3) Provide ample ventilation in quarters.

(4) Practice strict personal hygiene.

(5) Secure ample open air exercise.

(6) Avoid unnecessary exposure, chilling, and fatigue.

(7) Practice moderation in eating and drinking.

(8) Report to the hospital at the first sign of a cold, unusual mental or physical fatigue, or fever.

b. Measures for the enlisted members of combat crews:

(1) Proper ventilation of quarters or in barracks.

(2) Maximum utilization of available sleeping space in order to separate bunks as far as possible.

(3) Proper and ample clothing and bedding.

(4) Head to foot sleeping.

(5) Avoidance of crowding in places of gathering.

(6) The isolation of all individuals who are disabled by colds or other ailments either in quarters or hospital, depending upon the nature and severity of the ailment.

77. First-aid kits for treatment of combat crews.—*a*. From experience it is known that most airplane crashes occur away from the immediate vicinity of medical aid. The time intervening between a crash and the arrival of medical personnel and equipment varies from a few minutes to several days but is usually in excess of ½ hour. It is during this initial critical period of time that first aid is most essential. It is not only the period most likely to prove fatal from hemorrhage or burns, but the accompanying shock, if untreated, may ultimately cause death.

(1) Peacetime military flying is recognized as a hazardous occupation; wartime flying is, of course, much more so; operations will be conducted from temporary or improvised fields; there will be a considerable number of craft disabled by combat; and it can be expected that a considerable number of casualties will result from bullet or shell wounds in flight.

(2) During combat, particularly in multi-place airplanes, facilities should be provided for first aid to the wounded in flight, as an immediate landing might be impracticable due to position over enemy territory, water, or unfavorable terrain. To fulfill satisfactorily the requirements for an aeronautic first-aid kit, it must be light and compact and installed within reach of one or more members of the airplane crew while in flight. The contents must be designed to control hemorrhage, to dress and sterilize wounds and treat burns, and adapted for use by flying personnel.

(3) It is evident from the consideration of these factors that one or more aeronautic first-aid kits must be in each airplane at all times.

b. The Air Corps experimental model first-aid kit now in use is equipped with the following items:

1 dressing, for shell wound.
4 compresses, bandage, 2-inch.
16 compresses, adhesive, 1-inch.
1 tourniquet.

5 swabs, antiseptic, 1½ cc.
1 tube, ointment, burn, 4-ounce. (Tube collapsible with opening at large end.)
10 tablets, analgesic compound.

c. A first-aid kit, containing the items of equipment listed or similar items, should be available in each military airplane as follows:

(1) One each first-aid kit for airplanes, one or two place.
(2) Two each first-aid kits for airplanes with crews of three to six.
(3) Four each first-aid kits for airplanes with crews of seven or more.

Appendix I

DEFINITIONS

Acceleration.—An increase in speed or velocity.

Aeroembolism.—The effects produced by a rapid decrease of pressure below one atmosphere, such as may occur in aircraft flights to high altitude, and which is marked by the formation of nitrogen bubbles in the body tissues and fluids.

Aeroneurosis.—A chronic functional nervous disorder occurring in professional aviators, characterized by gastric distress, nervous irritability, fatigue of the higher voluntary mental centers, insomnia, and increased motor activity.

Aneroid barometer.—A barometer which indicates the atmospheric pressure by mechanical means.

Anoxia.—Term employed to describe oxygen deficiency in the body tissues.

Deceleration.—Decrease in velocity or speed.

Decompression.—The process of decompressing the body after it has been subjected to high pressure such as in deep sea diving; or the process of decompressing the body preparatory for a high altitude ascent.

Depth perception.—The ability to appreciate or discriminate the third dimension, to judge distance, and to orient one's self in relation to other objects in the visual field.

Escape mechanism.—A mode of response adopted by the individual for the purpose of protecting himself from the knowledge or consequences of his own shortcomings.

Metabolism.—The process within the body through which nourishment or food is converted for the use of the body into energy, living matter, etc., and also through which the living matter is changed or broken down into the products required within the cells or organism.

Psychiatry.—The practice or science of treating mental diseases.

Positive pressure cabin.—Airplane cabin sealed and equipped so as to regulate the air pressure at high altitudes; positive pressure suits have been developed for the same.

Sensory.—Conveying an impulse that results or tends to result in sensation, as a nerve.

Spacial orientation.—Includes an awareness of position in relation to a geographical point; in relation to other objects in space; or in relation to gravity.

Stratosphere.—Portion of the atmosphere above the troposphere where there is no temperature fall with increased altitude, rather a slight rise.

Troposphere.—That layer of air adjacent to the earth's surface within which there is a drop of temperature with the increase in altitude.

Appendix II

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